Previous Years' CBSE Board Questions

3.3 Electric Currents in Conductors

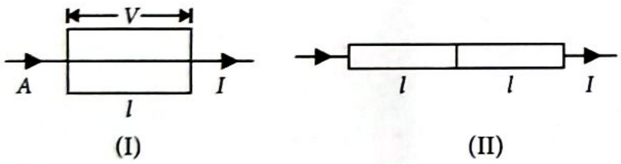
VSA (1 mark)

1. How does the random motion of free electrons in a conductor get affected when a potential difference is applied across its ends? *(Delhi 2014C)*

3.4 Ohm's Law

SA I (2 marks)

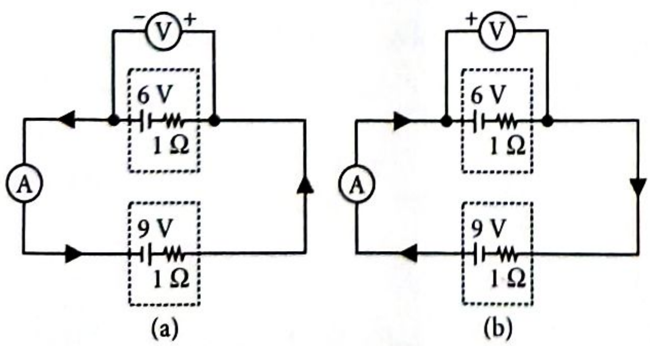
2. A metal rod of square cross-sectional area A having length l has current I flowing through it when a potential difference of V volt is applied across its ends (figure I). Now the rod is cut parallel to its length into two identical pieces and joined as shown in figure II. What potential difference must be maintained across the length of $2l$ so that the current in the rod is still I?



(Foreign 2016)

SA II (3 marks)

3. In the two electric circuits shown in the figure, determine the readings of ideal ammeter (A) and the ideal voltmeter (V).



(Delhi 2015C)

3.5 Drift of Electrons and the Origin of Resistivity

VSA (1 mark)

4. How is the drift velocity in a conductor affected with the rise in temperature? *(Delhi 2019)*

5. Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit. *(AI 2017C, Delhi 2014)*

6. Define the term drift velocity of charge carriers in a conductor and write its relationship with the current flowing through it. *(Delhi 2014)*

7. Write the expression for the drift velocity of charge carriers in a conductor of length 'l' across which a potential difference 'V' is applied. *(AI 2014C)*

8. When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction? *(Delhi 2012)*

9. Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires. *(AI 2010)*

SA I (2 marks)

10. Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor. *(Delhi 2015C)*

11. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. *(AI 2014)*

12. Explain the term 'drift velocity' of electrons in a conductor. Hence obtain the expression for

the current through a conductor in terms of 'drift velocity'. *(AI 2013)*

13. Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature. *(Delhi 2013C)*

14. Define mobility of a charge carrier. Write the relation expressing mobility in terms of relaxation time. Give its SI unit. *(AI 2013C)*

15. A conductor of length 'l' is connected to a dc source of potential 'V'. If the length of the conductor is tripled by gradually stretching it keeping 'V' constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected. Justify your answer. *(Foreign 2012)*

16. Define drift velocity. Write its relationship with relaxation time in terms of the electric field $\vec{E}$ applied to a conductor.
A potential difference V is applied to a conductor of length l. How is the drift velocity affected when V is doubled and l is halved? *(Foreign 2010)*

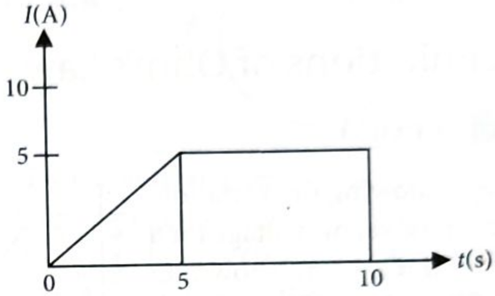
SA II (3 marks)

17. (a) Define the term 'conductivity' of a metallic wire. Write its SI unit.
(b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E. *(2018)*

18. (a) Find the relation between drift velocity and relaxation time of charge carriers in a conductor.
(b) A conductor of length L is connected to a d.c. source of e.m.f. V. If the length of the conductor is tripled by stretching it, keeping V constant. Explain how drift velocity would be affected. *(AI 2015)*

19. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electric field, drift speed ? *(1/3, Delhi 2015C)*

20. (a) Deduce the relation between current I flowing through a conductor and drift velocity $\vec{v}_d$ of the electrons.
(b) Figure shows a plot of current 'I' flowing through the cross-section of a wire versus the time 't'. Use the plot to find the charge flowing in 10 sec through the wire.



(AI 2015C)

21. Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons? Use this relation to deduce the expression for the electrical resistivity of the material. *(AI 2012)*

22. A conductor of length L is connected to a dc source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length $3L$, how will the drift velocity change? *(1/3, Delhi 2011)*

LA (5 marks)

23. (i) Derive an expression for drift velocity of electrons in a conductor. Hence deduce Ohm's law.
(ii) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?
(a) drift speed (b) current density
(c) electric current (d) electric field
Justify your answer. *(Delhi 2017)*

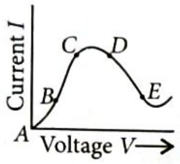
24. Define the term 'drift velocity' of charge carriers in a conductor. Obtain the expression for the current density in terms of relaxation time. *(2/5, Foreign 2014)*

25. (a) Derive the relation between current density '$\vec{j}$' and potential difference 'V' across a current carrying conductor of length 'l', area of cross-section 'A' and the number density 'n' of free electrons.
(b) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}.] *(Delhi 2012C)*

3.6 Limitations of Ohm's Law

VSA (1 mark)

26. Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of



(i) negative resistance
(ii) where Ohm's law is obeyed. *(Delhi 2015)*

3.7 Resistivity of Various Materials

VSA (1 mark)

27. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker ? *(AI 2012)*

28. Carbon and silicon both have four valence electrons each. How then are they distinguished ? *(Delhi 2011C)*

29. Define resistivity of a conductor. Write its S.I. unit. *(AI 2011C)*

SA I (2 marks)

30. (a) You are required to select a carbon resistor of resistance 47 kΩ ± 10% from a large collection. What should be the sequence of colour bands used to code it ?
(b) Write the characteristics of manganin which make it suitable for making standard resistance. *(Foreign 2011)*

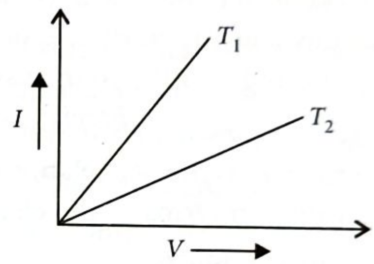
31. Define ionic mobility. Write its relationship with relaxation time. How does one understand the temperature dependence of resistivity of a semiconductor ? *(Foreign 2010)*

32. The sequence of coloured bands in two carbon resistors R_1 and R_2 is
(i) brown, green, blue
(ii) orange, black, green
Find the ratio of their resistances. *(AI 2010C)*

3.8 Temperature Dependence of Resistivity

VSA (1 mark)

33. I-V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperatures is lower and why?



(AI 2015)

34. Plot a graph showing the variation of resistivity of a conductor with temperature. *(Foreign 2015)*

35. Show variation of resistivity of copper as a function of temperature in a graph. *(Delhi 2014)*

36. Plot a graph showing variation of current versus voltage for the material GaAs. *(Delhi 2014)*

37. How does one explain increase in resistivity of a metal with increase of temperature ? *(AI 2014C)*

38. Plot a graph showing the variation of resistance of a conducting wire as a function of its radius. Keeping the length of the wire and its temperature as constant. *(Foreign 2013)*

39. Two materials Si and Cu, are cooled from 300 K to 60 K. What will be the effect on their resistivity ? *(Foreign 2013)*

40. Show on a graph, the variation of resistivity with temperature for a typical semiconductor. *(Delhi 2012)*

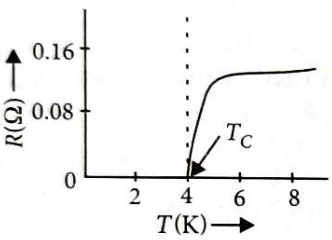
SA I (2 marks)

41. Draw a graph showing variation of resistivity with temperature for nichrome. Which property of nichrome is used to make standard resistance coils ? *(AI 2013C)*

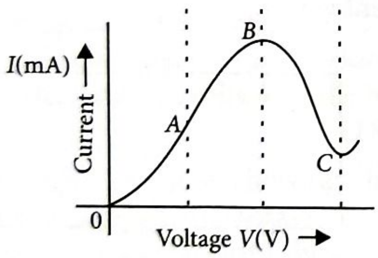
42. Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained ? *(Foreign 2011)*

SA II (3 marks)

43. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure is the resistance negative and why?



(2/3, AI 2019)

3.9 Electrical Energy, Power

VSA (1 mark)

44. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? Justify your answer. *(AI 2017)*

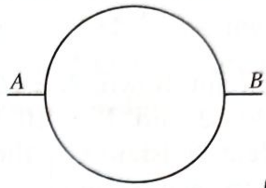
SA I (2 marks)

45. Two bulbs are rated (P_1, V) and (P_2, V). If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2. *(Delhi 2019)*

3.10 Combination of Resistors-Series and Parallel

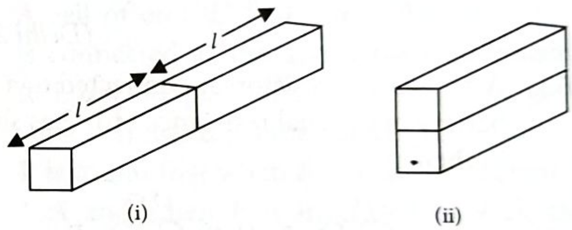
VSA (1 mark)

46. A wire of resistance $8R$ is bent in the form of a circle. What is the effective resistance between the ends of a diameter AB ?



(Delhi 2010)

47. Two identical slabs, of a given metal, are joined together, in two different ways, as shown in figures (i) and (ii). What is the ratio of the resistances of these two combinations ?



(Delhi 2010C)

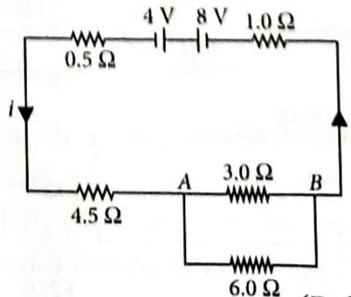
SA I (2 marks)

48. Two electric bulbs P and Q have their resistances in the ratio of 1 : 2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs. *(2018)*

49. Given the resistances of 1 Ω, 2 Ω and 3 Ω, how will you combine them to get an equivalent resistance of (i) $\frac{11}{3}$ Ω and (ii) $\frac{11}{5}$ Ω ? *(Foreign 2015)*

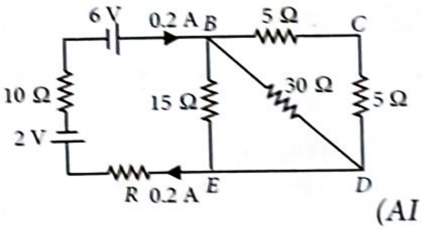
SA II (3 marks)

50. In the circuit shown in the figure, find the current through each resistor.



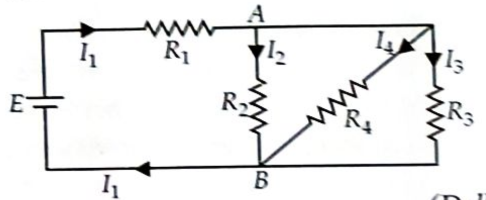
(Delhi 2015C)

51. Calculate the value of the resistance R in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points B and E?



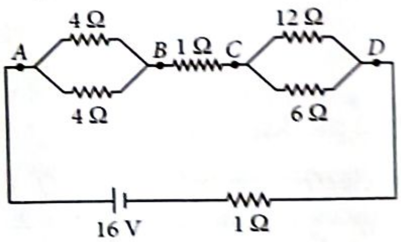
(AI 2012)

52. In the circuit shown, $R_1 = 4\ \Omega$, $R_2 = R_3 = 15\ \Omega$, $R_4 = 30\ \Omega$ and $E = 10$ V. Calculate the equivalent resistance of the circuit and the current in each resistor.



(Delhi 2011)

53. A network of resistors is connected to a 16 V battery of internal resistance of 1 Ω as shown in the figure.



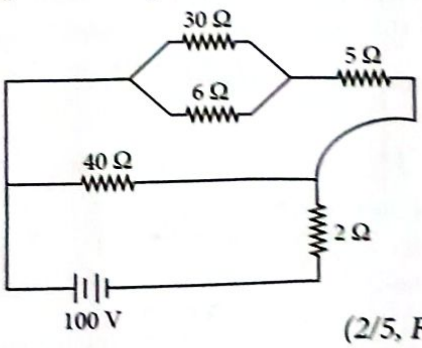
(a) Compute the equivalent resistance of the network.

(b) Obtain the voltage drops V_{AB} and V_{CD}.

(Foreign 2010)

LA (5 marks)

54. A 100 V battery is connected to the electric network as shown. If the power consumed in the 2 Ω resistor is 200 W, determine the power dissipated in the 5 Ω resistor.

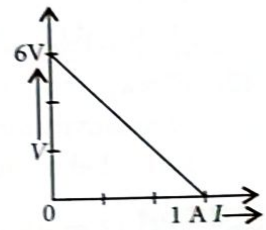


(2/5, Foreign 2014)

3.11 Cells, emf, Internal Resistance

VSA (1 mark)

55. The plot of the variation of potential difference across a combination of three identical cells in series versus current is shown in the figure. What is the emf and internal resistance of each cell?

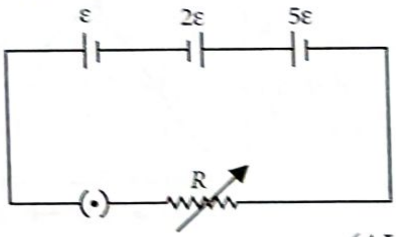


(AI 2016)

56. The emf of a cell is always greater than its terminal voltage. Why? Give reason. *(Delhi 2013)*

57. Why is the terminal voltage of a cell less than its emf ? *(AI 2013C)*

58. Three cells of emf ε, 2ε and 5ε having internal resistances r, $2r$ and $3r$ respectively are connected across a variable resistance R as shown in the figure. Find the expression for the current. Plot a graph for variation of current with R.



(AI 2010C)

SA I (2 marks)

59. A cell of emf 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined. *(AI 2014)*

60. (a) Distinguish between emf (ε) and terminal voltage (V) of a cell having internal resistance 'r'.
(b) Draw a plot showing the variation of terminal voltage (V) vs the current (I) drawn from the cell. Using this plot, how does one determine the internal resistance of the cell ? *(AI 2014C)*

61. A battery of emf E and internal resistance r when connected across an external resistance of 12 Ω, produces a current of 0.5 A. When connected across a resistance of 25 Ω, it produces a current of 0.25 A. Determine (i) the emf and (ii) the internal resistance of the cell. *(AI 2013C)*

62. A cell of emf E and internal resistance r is connected to two external resistances R_1 and R_2 and a perfect ammeter. The current in the circuit is measured in four different situations :

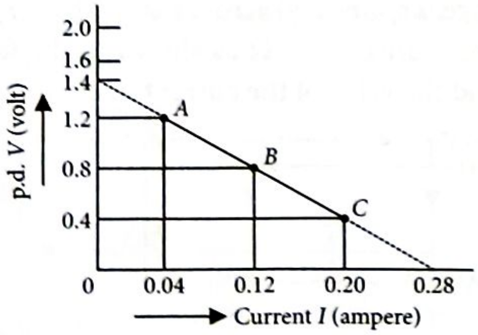
(i) without any external resistance in the circuit
(ii) with resistance R_1 only
(iii) with R_1 and R_2 in series combination
(iv) with R_1 and R_2 in parallel combination

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above. *(Delhi 2012)*

63. A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0.5 A, find

(i) The resistance of the resistor;
(ii) The terminal voltage of the battery *(Delhi 2012C)*

64. A straight line plot showing the terminal potential difference (V) of a cell as a function of current (I) drawn from it is shown in the figure. Using this plot, determine (i) the emf and (ii) internal resistance of the cell.



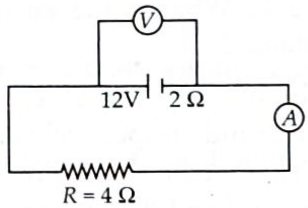
(Delhi 2011C)

SA II (3 marks)

65. Draw a graph showing the variation of current versus voltage in an electrolyte when an external resistance is also connected. *(1/3, AI 2019)*

66. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

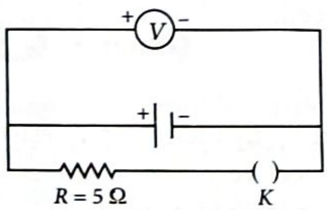
(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



(AI 2017)

67. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.
It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r. *(Delhi 2015)*

68. Write any two factors on which internal resistance of a cell depends. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5 Ω as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.



(AI 2010)

LA (5 marks)

69. A cell, with a finite internal resistance r, is connected across two external resistances R_1 and R_2 ($R_1 > R_2$), one by one. In which case would the terminal potential difference of the cell be more ? *(2/5, Delhi 2010C)*

3.12 Cells in Series and in Parallel

VSA (1 mark)

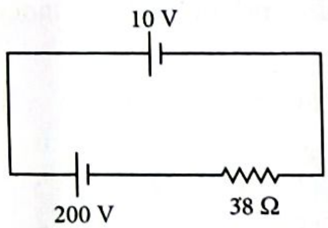
70. Under what condition will the current in a wire be the same when connected in series and in parallel of n identical cells each having internal resistance r and external resistance R? *(AI 2019)*

71. Two identical cells, each of emf E, having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through this resistance? *(AI 2013)*

72. Two cells, of emf 2ε and ε, and internal resistance $2r$ and r respectively, are connected in parallel. Obtain the expression for the equivalent emf and the internal resistance of the combination. *(AI 2010C)*

SA I (2 marks)

73. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit.

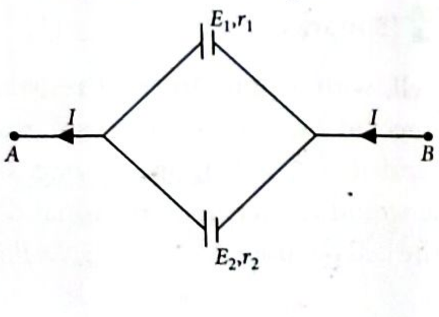


(2018)

74. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. *(Delhi 2016)*

SA II (3 marks)

75. Two cells of emf E_1, E_2 and internal resistance r_1 and r_2 respectively are connected in parallel as shown in the figure.



Deduce the expression for

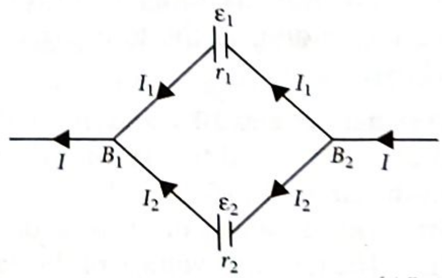
(i) The equivalent emf of the combination

(ii) The equivalent resistance of the combination

(iii) The potential difference between the points A and B. *(Foreign 2012)*

76. Two cells of emfs E_1 and E_2 and internal resistance r_1 and r_2 are connected in parallel. Obtain the expression for the emf and internal resistance of a single equivalent cell that can replace this combination ? *(2/3, Foreign 2011)*

77. Two cells of emf ε_1 and ε_2 having internal resistances r_1 and r_2 respectively are connected in parallel as shown. Deduce the expressions of the equivalent emf a cell which can replace the combination between the points B_1 and B_2.

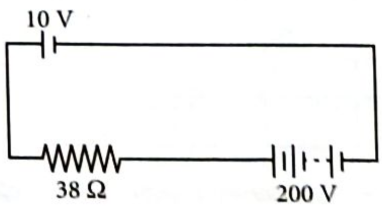


(AI 2011C)

3.13 Kirchhoff's Laws

VSA (1 mark)

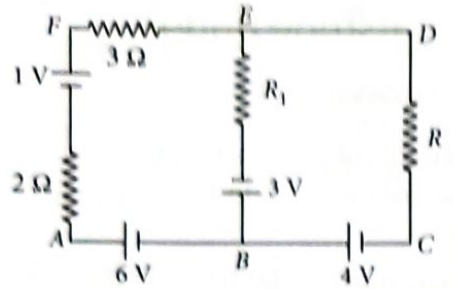
78. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit.



(Delhi 2013)

SA I (2 marks)

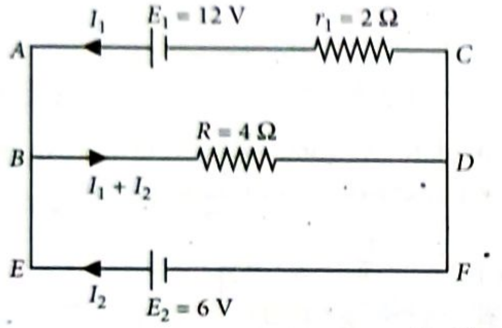
79. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the BE of the electric network shown in the figure.



(AI 2015)

80. State Kirchhoff's rules. Explains briefly how these rules are justified. (Delhi 2014)

81. In the electric network shown in the figure, use Kirchhoff's rules to calculate the power consumed by the resistance $R = 4\ \Omega$.



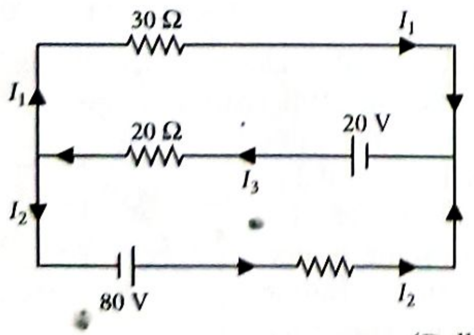
(Delhi 2014C)

82. An ammeter of resistance 0.80 Ω can measure current up to 1.0 A:

(i) What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A?

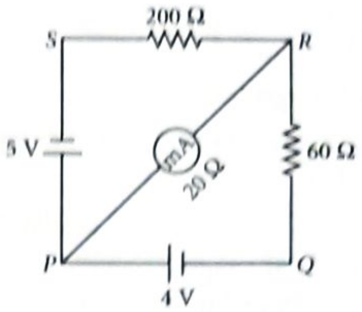
(ii) What is the combined resistance of the ammeter and the shunt? (Delhi 2013)

83. Use Kirchhoff's rules to determine the value of the current I_1 flowing in the circuit shown in the figure.



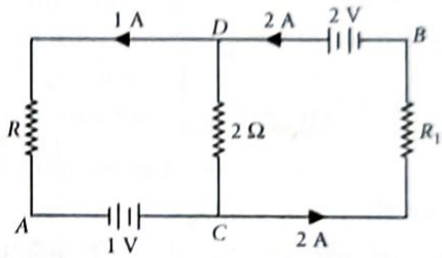
(Delhi 2013C)

84. The network *PQRS*, shown in the circuit diagram, has the batteries of 4 V and 5 V and negligible internal resistance. A milliammeter of 20 Ω resistance is connected between *P* and *R*. Calculate the reading in the milliammeter.



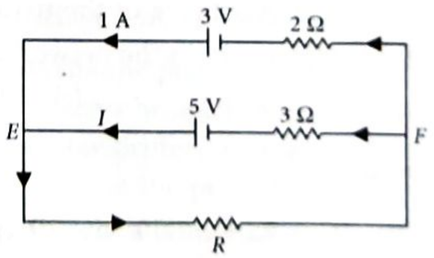
(AI 2012C)

85. In the given circuit, assuming point *A* to be at zero potential, use Kirchhoff's rules to determine the potential at point *B*.



(AI 2011)

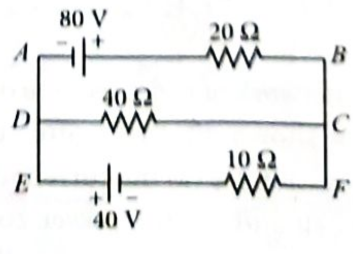
86. Using Kirchhoff's rules in the given circuit, determine (i) the voltage drop across the unknown resistor *R* and (ii) the current *I* in the arm *EF*.



(AI 2011C)

SA II (3 marks)

87. Using Kirchhoff's rules, calculate the current through the 40 Ω and 20 Ω resistors in the following circuit.



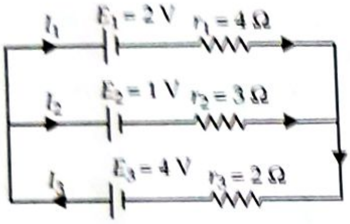
(Delhi 2019)

88. Using Kirchhoff's rules determine the value of unknown resistance R in the circuit so that no current flows through 4 Ω resistance. Also find the potential difference between A and D.

(Delhi 2012)

89. (a) State Kirchhoff's rules.

(b) Use these rules to write the expressions for the currents I_1, I_2 and I_3 in the circuit diagram shown.



(AI 2010)

90. (a) State Kirchhoff's rules.

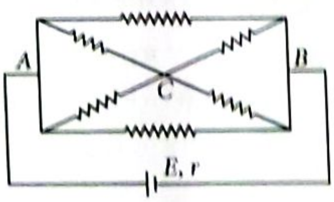
(b) A battery of 10 V and negligible internal resistance is connected across the diagonally opposite corners of a cubical network consisting of 12 resistors each of 1 Ω resistance. Use Kirchhoff's rules to determine (i) the equivalent resistance of the network, and (ii) the total current in the network.

(AI 2010C)

LA (5 marks)

91. (i) State the two Kirchhoff's laws. Explain briefly how these rules are justified.

(ii) The current is drawn from a cell of emf E and internal resistance r connected to the network of resistors each of resistance r as shown in the figure. Obtain the expression for (a) the current drawn from the cell and (b) the power consumed in the network.



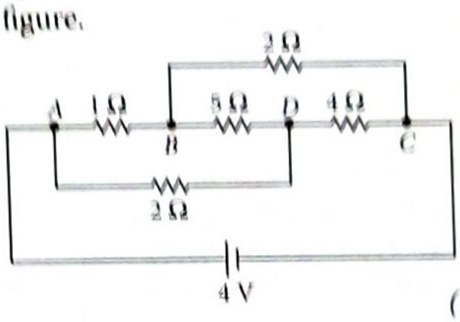
(Delhi 2017)

3.14 Wheatstone Bridge

SA I (2 marks)

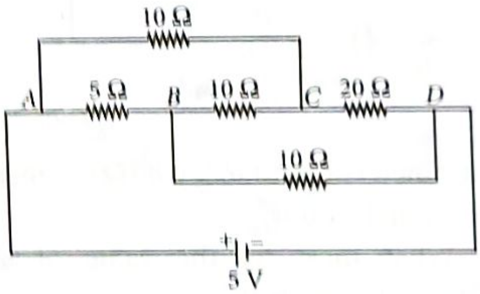
92. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge. *(Delhi 2015)*

93. Calculate the current drawn from the battery by the network of resistors shown in the figure.



(AI 2015C)

94. Calculate the value of current drawn form a 5 V battery in the circuit as shown.



(Foreign 2013)

LA (5 marks)

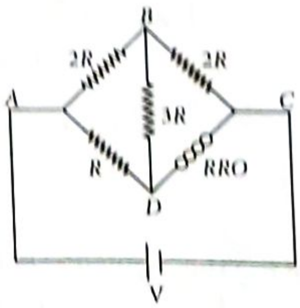
95. (a) State Kirchhoff's rules for an electric network.

(b) Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheastone bridge.

(3/5, Delhi 2013, 2010C)

96. Use Krichhoff's rules to obtain the balance condition in a Wheatstone bridge.

Calculate the value of R in the balance condition of the Wheatstone bridge, if the carbon resistor connected across the arm CD has the colour sequence red, red and orange, as is shown in the figure.

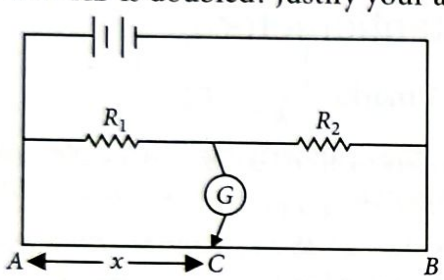


If now the resistances of the arms BC and CD are interchanged, to obtain the balance condition, another carbon resistor is connected in place of R. What would now be the sequence of colour bands of the carbon resistor ? *(Delhi 2012C)*

3.15 Meter Bridge

VSA (1 mark)

97. In an experiment on meter bridge, if the balancing length AC is 'x', what would be its value, when the radius of the meter bridge wire AB is doubled? Justify your answer.

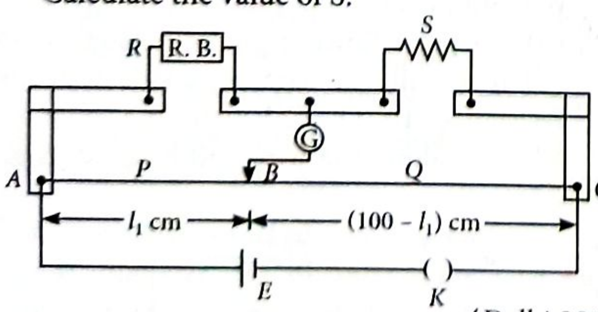


(AI 2011C)

98. In a meter bridge, two unknown resistances R and S when connected in the two gaps, give a null point at 40 cm from one end. What is the ratio of R and S ? *(Delhi 2010C)*

SA II (3 marks)

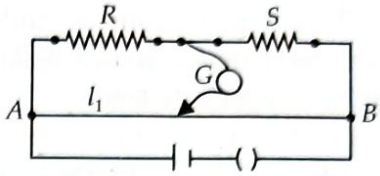
99. What is end error in a metre bridge ? How is it overcome ? The resistances in the two arms of the metre bridge are $R = 5\ \Omega$ and S respectively.
When the resistance S is shunted with an equal resistance, the new balance length found to be $1.5\ l_1$, where l_1 is the initial balancing length. Calculate the value of S.



(Delhi 2019)

100. State the underlying principle of meter bridge. Draw the circuit diagram and explain how the unknown resistance of a conductor can be determined by this method. *(AI 2019)*

101. (a) Write the principle of working of a metre bridge.
(b) In a metre bridge, the balance point is found at a distance l_1 with resistances R and S as shown in the figure.

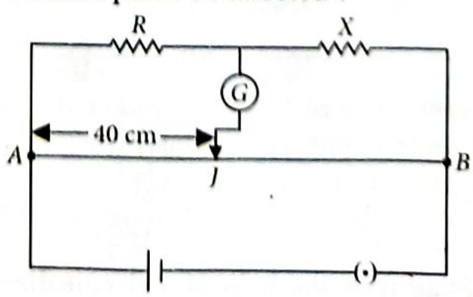


An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S. *(AI 2017)*

102. With the help of the circuit diagram, explain the working principle of meter bridge. How is it used to determine the unknown resistance of a given wire ? Write the necessary precautions to minimize error in the result. *(AI 2015C)*

103. Answer the following :
(a) Why are the connections between the resistors in a meter bridge made of thick copper strips?
(b) Why is it generally preferred to obtain the balance point in the middle of the metre bridge wire?
(c) Which material is used for the meter bridge wire and why? *(AI 2014)*

104. Write the principle on which the working of a meter bridge is based. In an experiment of meter bridge, a student obtains the balance point at the point J such that $AJ = 40$ cm as shown in the figure. The values of 'R' and 'X' are both doubled and then interchanged. Find the new position of the balance point. If the galvanometer and battery are also interchanged, how will the position of balance point be affected ?

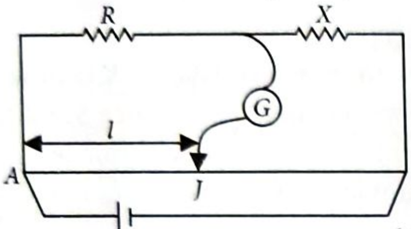


(AI 2012C)

105. In the meter bridge experiment, balance point was observed at J with $AJ = l$.

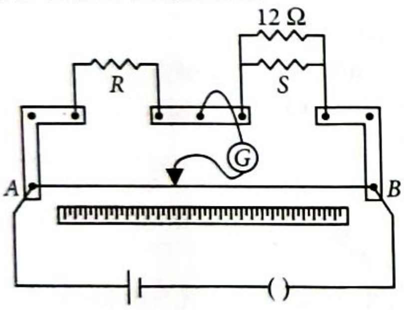
(i) The value of R and X were doubled and then interchanged. What would be the new position of balance point ?

(ii) If the galvanometer and battery are interchanged at the balance position, how will the balance point get affected ?



(AI 2011)

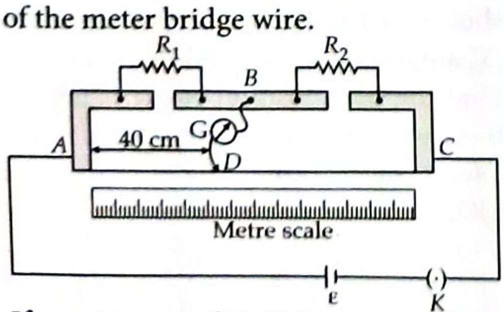
106. In a meter bridge, the null points is found at a distance of 40 cm from A. If a resistance of 12 Ω is connected in parallel with S, the null point occurs at 50.0 cm from A. Determine the values of R and S.



(Delhi 2010)

LA (5 marks)

107. In the meter bridge experimental set up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meter bridge wire.



If a resistance of 10 Ω is connected in series with R_1, null point is obtained at $AD = 60$ cm. Calculate the values of R_1 and R_2.

(2/5, Delhi 2013)

108. (a) State with the help of a circuit diagram, the working principle of a meter bridge. Obtain the expression used for determining the unknown resistance.

(b) What happens if the galvanometer and cell are interchanged at the balance point of the bridge ?

(c) Why is it considered important to obtain the balance point near the mid-point of the wire ? *(Delhi 2011C)*

109. Draw a circuit diagram for determining the unknown resistance R using meter bridge. Explain briefly its working giving the necessary formula used. *(2/5, Delhi 2010C)*

3.16 Potentiometer

VSA (1 mark)

110. State the underlying principle of a potentiometer. *(Delhi 2014C)*

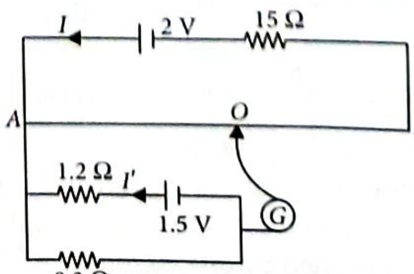
111. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for r in terms of ε, V and R. *(Delhi 2011)*

SA I (2 marks)

112. In a potentiometer arrangement for determining the emf of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of 9 Ω is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell. *(2018)*

113. (i) State the principle of working of a potentiometer.

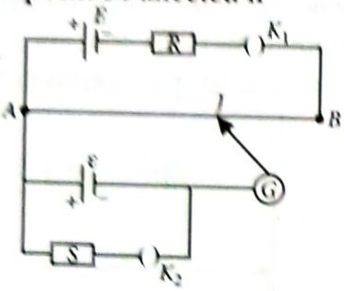
(ii) In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the potential gradient along the wire and balance length $AO (= l)$.



(Delhi 2016)

114. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a cell. *(AI 2013)*

115. Two students 'X' and 'Y' preform an experiment on potentiometer separately using the circuit given : Keeping other parameters unchanged, how will the position of the null point be affected if



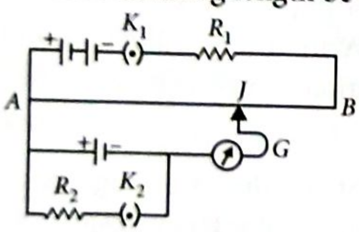
(i) 'X' increases the value of resistance R in the set-up by keeping the key K_1 closed and the key K_2 open ?

(ii) 'Y' decreases the value of resistance S in the set-up, while the key K_2 remains open and the key K_1 closed ?

(Foreign 2012)

SA II (3 marks)

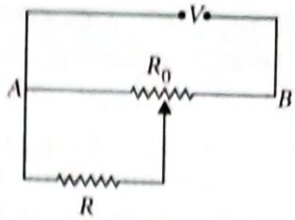
116. (a) For the circuit shown in the figure, how would the balancing length be affected, if



(i) R_1 is decreased,
(ii) R_2 is increased,
the other factors remaining the same in the circuit? Justify your answer in each case.

(b) Why is a potentiometer preferred over a voltmeter? Give reason. *(AI 2019)*

117. A resistance of R draws current from a potentiometer. The potentiometer wire AB, has a total resistance of R_0. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer wire.



(Delhi 2017)

118. Draw a circuit diagram of a potentiometer. State its working principle. Drive the necessary formula to describe how it is used to compare the emfs of the two cells. *(AI 2015C)*

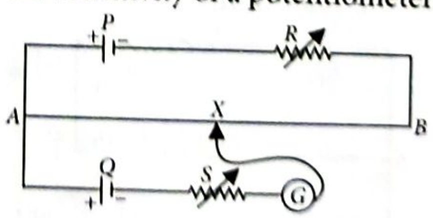
119. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm. *(Delhi 2014)*

120. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm. *(Delhi 2014)*

121. (a) State the underlying principle of a potentiometer. Why is it necessary to (i) use a long wire, (ii) have uniform area of cross-section of the wire and (iii) use a driving cell whose emf is taken to be greater than the emfs of the primary cells ?

(b) In a potentiometer experiment, if the area of the cross-section of the wire increases uniformly from one end to the other, draw a graph showing how potential gradient would vary as the length of the wire increases from one end. *(AI 2014C)*

122. State the underlying principle of a potentiometer. Write two factors on which the sensitivity of a potentiometer depends.

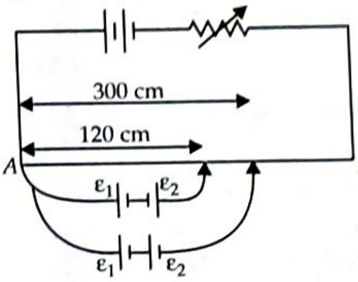


In the potentiometer circuit shown in the figure, the balance point is at X. State, giving reason, how the balance point is shifted when

(i) Resistance R is increased ?

(ii) Resistance S is increased, keeping R constant ? *(2/3, Delhi 2013C)*

123. In the figure a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1. How is the sensitivity of a potentiometer increased?



(Delhi 2012)

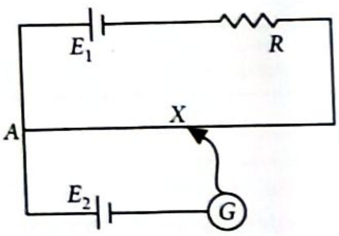
124. (a) State the underlying principle of potentiometer.

(b) Describe briefly, giving the necessary circuit diagram, how a potentiometer is used to measure the internal resistance of a given cell. *(Foreign 2011)*

125. Write the principle of working of a potentiometer. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a given cell. *(Delhi 2010)*

LA (5 marks)

126. (i) In the circuit diagram given below, AB is a uniform wire of resistance 15 Ω and length 1 m. It is connected to a cell E_1 of emf 2V and negligible internal resistance and a resistance R. The balance point with another cell E_2 of emf 75 mV is found at 30 cm from end A. Calculate the value of R.

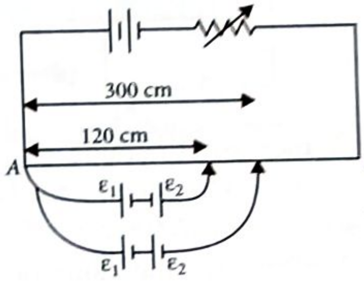


(ii) Why is potentiometer preferred over a voltmeter for comparison of emf of cells ?

(iii) Draw a circuit diagram to determine internal resistance of a cell in the laboratory. *(Foreign 2016)*

127. (a) State the principle of a potentiometer. Define potential gradient. Obtain an expression of potential gradient in terms of resistivity of the potentiometer wire.

(b) Figure shows a long potentiometer wire AB having a constant potential gradient. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of $l_1 = 120$ cm and $l_2 = 300$ cm from the end A. Determine (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1 only.



(Foreign 2014)

128. (a) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.

(b) Write two possible causes for one sided deflection in a potentiometer experiment. *(Delhi 2013)*

129. (a) State the working principle of a potentiometer. Draw a circuit diagram to compare emf of two primary cells. Drive the formula used.

(b) Which material is used for potentiometer wire and why ?

(c) How can the sensitivity of a potentiometer be increased ? *(Delhi 2011C)*

130. (a) Write the underlying principle of a potentiometer.

(b) Draw the circuit diagram of the experimental set-up used for determining the internal resistance of a cell by potentiometer. Write the necessary formula used. *(3/5, Delhi 2010C)*

Detailed Solutions

1. Conductors contain free electrons. In the absence of any external electric field, the free electrons are in random motion just like the molecules of gas in a container and the net current through wire is zero.
If the ends of the wire are connected to a battery, an electric field (E) will setup at every point within the wire. Due to electric effect of the battery, the electrons will experience a force in the direction opposite to E.

2. From Ohm's law, we have
$V = IR$

$\Rightarrow \quad V = I\rho\frac{l}{A}$ ...(i)

When the rod is cut parallel, and rejoined by length, the length of the conductor becomes $2l$, whereas the area decrease to $\frac{A}{2}$. If the current remains the same the potential changes as

$V = I\rho\frac{2l}{A/2} = 4\times I\rho\frac{l}{A} = 4V$ [Using (i)]

The new potential applied across the metal rod will be four times the original potential (V).

3. In First Circuit
Reading of ideal voltmeter = 6 V
Net potential difference = 9 + 6 = 15 V
Total resistance = 1 + 1 = 2 Ω
Current in ammeter $= \frac{V}{R} = \frac{15}{2} = 7.5$ A
In Second Circuit
Reading of ideal volt meter = 6 V
Net potential difference = 9 – 6 = 3 V
Total resistance = 1 + 1 = 2 Ω
Current in ammeter $= \frac{V}{R} = \frac{3}{2} = 1.5$ A

4. Drift velocity, $v_d = \frac{eE\tau}{m}$ i.e., $v_d \propto \tau$

By increasing temperature relaxation time decreases, therefore we can say that the drift velocity decreases with the rise in temperature.

5. The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric field it creates.
It is reciprocal of resistivity (ρ).

Electrical conductivity, $(\sigma) = \frac{1}{\rho} = \frac{j}{E}$

S.I. unit = mho m^{-1} or (ohm m)$^{-1}$ or S m^{-1}

6. When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time. This velocity is known as drift velocity (v_d).

Relationship between current (I) and drift velocity (v_d), $I = neAv_d$
where ne = amount of charge inside the conductor
A = area of cross-section of conductor

7. $\because \quad I = neAv_d$

$\therefore \quad v_d = \frac{V}{ne\rho l} \quad \left\{\text{Using } A = \frac{\rho l}{R}\right\}$

8. Yes, all the electrons will move in same direction during drift due to external electric field.

9. Since the wires are connected in series, current I through both is same. Therefore ratio of drift velocities

$\frac{v_X}{v_Y} = \frac{I/n_XeA_X}{I/n_YeA_Y}$

where, n_X, n_Y = respective electron densities
A_X, A_Y = cross-sectional areas

$\Rightarrow \quad \frac{v_X}{v_Y} = \frac{n_Y}{n_X} = \frac{1}{2}$ (Given $A_X = A_Y$, $n_X = 2n_Y$)

$\Rightarrow \quad v_X : v_Y = 1 : 2$

10. As we know that
$I = neAv_d$

Also current density j is given by $j = \frac{I}{A}$

$\therefore \quad |\vec{j}| = \frac{ne^2}{m}\tau|\vec{E}| \qquad \left(\because v_d = \frac{e\tau E}{m}\right)$

$\because \quad \vec{j}$ is parallel to $\vec{E}$,

$\therefore \quad \vec{j} = \frac{ne^2}{m}\tau\vec{E}$

$\because \quad \sigma = \frac{1}{\rho} = \frac{ne^2}{m}\tau$

$\therefore \quad \vec{j} = \frac{\vec{E}}{\rho}$

11. $I = neAv_d$

$$v_d = \frac{I}{neA} = \frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}\ \text{m s}^{-1}$$

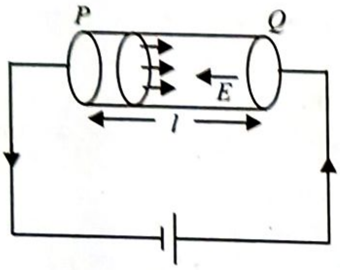
$= 1.042\times10^{-3}$ m s^{-1} ≈ 1 mm s^{-1}

12. *Refer to answer 6.*

Total number of free electrons in a conductor PQ of length l, cross-sectional area A having n free electrons per unit volume is

$N = n \times$ volume of conductor PQ

or $N = nAl$



Time 't' in which an electron moves from P to Q, all N free electrons pass through cross section Q.

$$t = \frac{l}{v_d}$$

where v_d is the drift velocity of electrons in the conductor.

So electric current flowing through conductor is given by

$$I = \frac{q}{t} = \frac{Ne}{t} = \frac{nAle}{l/v_d} \text{ or } I = neAv_d$$

This gives the relation between electric current and drift velocity.

13. Drift velocity $v_d = \frac{e\vec{E}}{m}\tau$, where E is electric field strength. And the relation between current and drift velocity is $I = neAv_d$.

$$\therefore \quad \frac{I}{A} = \frac{ne^2\tau}{m}E \Rightarrow j = \sigma AE$$

$$\sigma = \frac{ne^2\tau}{m} = \frac{1}{\rho} \text{ or, } \rho = \frac{m}{ne^2\tau}$$

With rise of temperature, the rate of collision of electrons with ions of lattice increases, so relaxation time decreases. As a result resistivity of the material increases with the rise of temperature, hence the resistance.

14. Mobility of a charge carrier is defined as the drift velocity of the charge carrier per unit electric field.

It is generally denote by μ.

$$\mu = \frac{v_d}{E}$$

The SI. unit of mobility is m^2 V^{-1} s^{-1}.

Mobility in term of relaxation time :

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau$$

In magnitude,

$$v_d = \frac{eE}{m}\tau \text{ or } \frac{v_d}{E} = \frac{e\tau}{m}$$

$$\mu = \frac{e\tau}{m}$$

15. (i) We know that $v_d = -\frac{eV\tau}{ml} \Rightarrow v_d \propto \frac{1}{l}$

When length is tripled, the drift velocity becomes one-third.

(ii) $R = \rho\frac{l}{A} = \rho\frac{l\times l}{A\times L} = \rho\frac{l^2}{V}$, $l' = 3l$

New resistance

$$R' = \rho\frac{l'}{V'} = \rho\times\frac{(3l)^2}{V} = 9R$$

$R' = 9R$

Hence, the new resistance will be 9 times the original.

16. Drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied. It is given by

$$\vec{v}_d = \frac{e\vec{E}}{m}\tau; v_d = \frac{eV}{ml}\tau$$

where m = mass of electron, e = charge of electron
E = electric field applied

If $V' = 2V$ and $l' = l/2$, then

$$v_d' = \frac{e(2V)}{m\times l/2}\tau = \frac{4eV}{ml}\tau = 4v_d$$

Becomes 4 times.

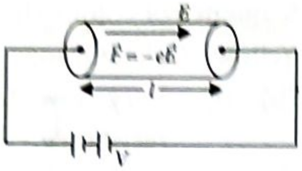
17. (a) *Refer to answer 5.*

(b) The electric field E exerts an electrostatics force $-Ee$.

Acceleration of each electron, $\vec{a} = \frac{-e\vec{E}}{m}$ ...(i) where,

m = mass of an electron

e = charge on an electron



$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + ... + \vec{v}_n}{n}$$

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + ... + (\vec{u}_n + \vec{a}\tau_n)}{n}$$

where,

$\vec{u}_1, \vec{u}_2 \rightarrow$ thermal velocities of the electrons

$\vec{a}\tau_1, \vec{a}\tau_2 \rightarrow$ velocities acquired by electrons

$\tau_1, \tau_2 \rightarrow$ time elapsed after the collision

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + \vec{u}_n)}{n} + \frac{\vec{a}(\tau_1 + \tau_2 + ... + \tau_n)}{n}$$

Since $\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_n}{n} = 0$, we get

$\therefore \quad v_d = a\tau, \qquad$ ...(ii)

where, $\tau = \frac{\tau_1 + \tau_2 + \tau_3 + ... + \tau_n}{n}$ is the average time elapsed.

Substituting the value of a in equation (ii) from equation (i), we have

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau \qquad ...(iii)$$

Hence average drift speed, $v_d = \frac{eE}{m}\tau$.

Electric current flowing through the conductor

$$I = \frac{q}{t} = \frac{-Ne}{t} = \frac{-nAle}{l/v_d}$$

$$I = -neAv_d = \frac{ne^2A\tau}{m}E$$

$$\Rightarrow \quad j = \frac{I}{A} = \left(\frac{ne^2\tau}{m}\right)E = \sigma E$$

18. (a) *Refer to answer 17(b).*

(b) In terms of potential difference, $v_d = \frac{eV}{Lm_e}\tau$

So, tripling the length of the conductor $l' = 3L$ and keeping V constant, the drift velocity will reduce to one third of initial value.

$$v_d' = \frac{v_d}{3}$$

19. Current is constant in non-uniform cross-section.

20. (a) *Refer to answer 12.*

(b) Area under I-t curve on t-axis is charge flowing through the conductor

$$Q = \frac{1}{2} \times 5 \times 5 + (10 + 5) \times 5 = 37.5 \text{ C}$$

21. The average time interval between two successive collisions for the free electrons drifting within a conductor due to the action of the applied electric field is called relaxation time.

Relation between relaxation time and drift velocity,

$$v_d = \left(\frac{-eE\tau}{m}\right)$$

Since $i = -ne\,Av_d$

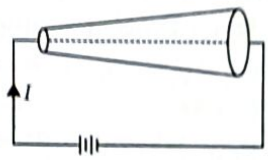
$i = ne^2A\,\tau V/ml$

$$\therefore \quad \frac{V}{i} = \frac{ml}{ne^2A\tau} = \frac{\rho l}{A} \qquad \therefore \ \rho = \frac{m}{(ne^2\tau)}$$

22. *Refer to answer 18(b).*

23. (i) *Refer to answer 17(b).*

(ii) (c) Electric current: The rate of flow of charge through (a non-uniform conductor) a conductor is same, hence current remains constant.



As area of cross-section of the conductor is varying so current density through wire and drift velocity of electron will not be same.

24. *Refer to answer 16 and 17(b).*

25. (a) Consider a conductor of length l and cross-sectional area A. When a potential difference V is applied across its ends, the current produced is I. If n is the number of electron per unit volume in the conductor and v_d the drift velocity of electrons then the relation between current and drift velocity is

$I = -\,ne\,Av_d \qquad$ ...(i)

Where $-e$ is the charge on electron

$(e = 1.6 \times 10^{-19}\text{C})$

Electric field produced at each point of wire,

$$E = \frac{V}{l} \qquad ...(ii)$$

If τ is relaxation time and E is electric field strength, then drift velocity.

$$v_d = -\frac{e\tau E}{m} \qquad ...(iii)$$

Putting this value of v_d in eqn (i)

$$I = -n eA\left(-\frac{e\tau}{m}E\right)$$

$$I = \frac{ne^2\tau}{m}AE \qquad \text{...(iv)}$$

As $E = \frac{V}{l}$ (from (ii))

$$I = \frac{ne^2\tau A}{m}\frac{V}{l}$$

$$\frac{V}{I} = \frac{m}{ne^2\tau}\cdot\frac{l}{A} \Rightarrow V = \frac{ml}{ne^2\tau}\cdot\frac{I}{A}$$

$$V = \frac{ml}{ne^2\tau}j \qquad \left[\because \frac{I}{A} = j\right]$$

(b) *Refer to answer 11.*

26. (i) Region *DE* has negative resistance property because current decreases with increase in voltage or slope of *DE* is negative.
(ii) Region *BC* obeys Ohm's law because current varies linearly with the voltage.

27. $R_{Cu} = R_m$

$$\rho_{Cu}\frac{l_{Cu}}{A_{Cu}} = \rho_m\frac{l_m}{A_m}$$

Here $l_{Cu} = l_m$

as $\rho_m > \rho_{Cu}$

$$\frac{\rho_{Cu}}{A_{Cu}} = \frac{\rho_m}{A_m} \Rightarrow \frac{\rho_m}{\rho_{Cu}} = \frac{A_m}{A_{Cu}}$$

As, $\rho_m > \rho_{Cu}$
So, $A_m > A_{Cu}$
Manganin wire is thicker than copper wire.

28. For both, valence electrons are same. The energy gap of Si is 1.1eV while for C is 5.44 eV. Carbon behaves as an insulator while Si as semiconductor.

29. The specific resistance of a conductor of unit length and unit cross-sectional area is called resistivity of the conductor.

$$\because \quad R = \rho\frac{l}{A}$$

For $l = 1$ m, $A = 1$ m^2
$R = \rho$
Its SI unit is Ω m.

30. (a) Resistance = 47 kΩ ± 10%
= 47 × 10^3 Ω ± 10%

Sequence of colour should be :
Yellow, Violet, Orange and Silver
(b) (i) Very low temperature coefficient of resistance.
(ii) High resistivity.

31. Mobility of an ion is defined as the drift velocity per unit electric field *i.e.*,

$$\mu = \frac{v_d}{E} = \frac{e\tau}{m}$$

Its unit is m^2/Vs.

When temperature increases, covalent bonds of neighbouring atoms break and charge carriers become free to cause conductive, so resistivity of semi-conductor decreases with rise of temperature.

32. (i) We know that the numbers for brown, green and blue are 1, 5 and 6 respectively
∴ $R_1 = 15 \times 10^6\ \Omega$
(ii) We know that the numbers for orange, black and green are 3, 0 and 5 respectively.
$R_2 = 30 \times 10^5\ \Omega$
∴ Ratio of their resistances is

$$\frac{R_1}{R_2} = \frac{15\times10^6}{30\times10^5} = \frac{10}{2} = \frac{5}{1} = 5:1$$

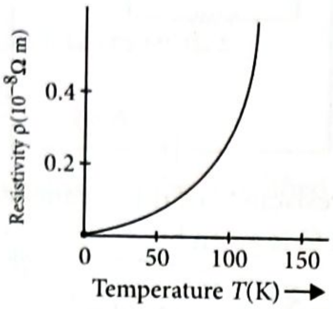
33. As $R = \frac{\Delta V}{\Delta I}$

so in *I-V* graph, $R \propto \frac{1}{(\text{Slope of } I - V \text{ graph})}$

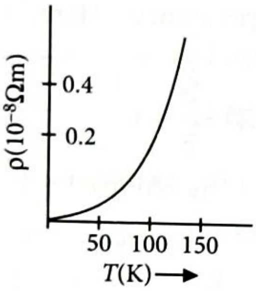
∴ $R_1 < R_2$
Resistance of metalic wire increases with temperature.
Hence, $T_1 < T_2$.

34. The resistivity of a metallic conductor is given by
$\rho = \rho_0[1 + \alpha(T - T_0)]$
where
ρ_0 = Resistivity at reference temperature
T_0 = Reference temperature
α = Coefficient of resistivity
From the above relation, we can say that the graph between resistivity of a conductor with temperature is straight line. But, at temperatures much lower than 273 K (*i.e.*, 0°C), the graph

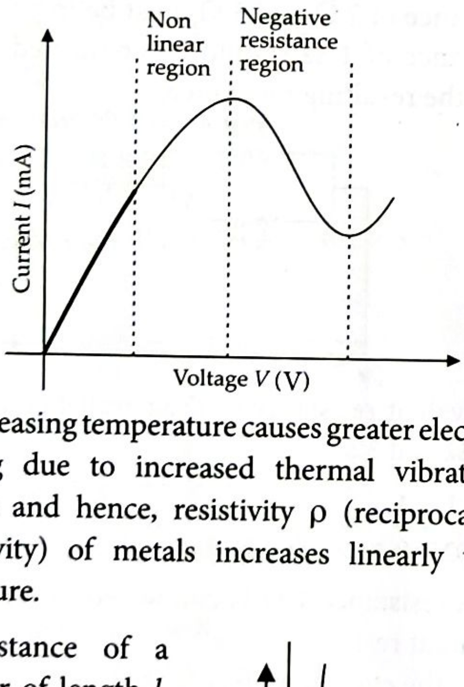
deviates considerably from a straight line as shown in the figure.



35. The variation of resistivity of copper with temperature is as shown in figure.



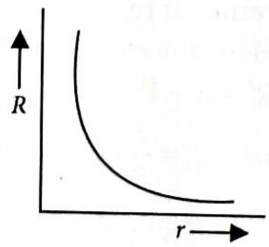
36. Variation of current versus voltage for GaAs.



37. Increasing temperature causes greater electron scattering due to increased thermal vibrations of atoms and hence, resistivity ρ (reciprocal of conductivity) of metals increases linearly with temperature.

38. Resistance of a conductor of length l, and radius r is given by

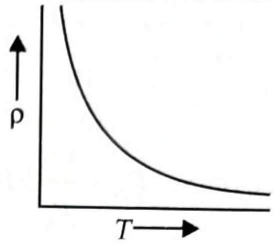
$$R = \rho\frac{l}{\pi r^2}$$



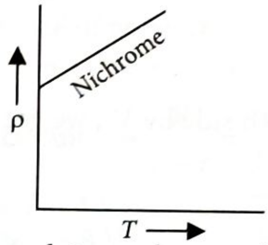
39. In silicon, the resistivity increases with decrease in temperature.

In copper, the resistivity decreases with decrease in temperature.

40. The variation of resistivity with temperature for a typical semiconductor is as shown in figure.



41. Variation of resistivity with temperature for nichrome



Nichrome is used to make standard resistance coils because the temperature coefficient of resistivity of nichrome is negligible.

42. *Refer to answer 40.*

In semiconductor the number density of free electrons (n) increases with increase in temperature (T) and consequently the relaxation period decreases. But the effect of increase in n has higher impact than decrease of τ. So, resistivity decreases with increase in temperature.

43. (i) Resistance of Hg below 4 K is zero so it behaves like a superconductor. Between $T = 4$ K to 5 K resistance rises linearly and beyond $T = 5$ K resistance becomes constant.

(ii) In region BC this material shows negative resistance property because current decreases with increase in voltage or slope of BC is negative.

44. Heat dissipated in a wire is given by

$$H = I^2Rt$$

$$H = \frac{I^2\rho lt}{A} \quad \left(\because R = \frac{\rho l}{A}\right)$$

For same current I, length l and area A, H depends on ρ

$\therefore$ $H \propto \rho$ and $\rho_{nichrome} > \rho_{copper}$

Hence, nichrome wire will heated up more.

45. In series :

Resistances of the bulbs,

$$R_1 = \frac{V^2}{P_1}, R_2 = \frac{V^2}{P_2}$$

Equivalent resistance, $R = R_1 + R_2$

If P is the effective power of the combination, then

$$\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2} \quad \text{or} \quad \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$

In parallel :

Resistance of the bulbs, $R_1 = \frac{V^2}{P_1}$, $R_2 = \frac{V^2}{P_2}$

As the bulbs are connected in parallel, their effective resistance R is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Multiplying both side by V^2, we get

$$\frac{V^2}{R} = \frac{V^2}{R_1} + \frac{V^2}{R_2}$$

or $P = P_1 + P_2$

46. Resistance of each semi-circular part of circle is $4R$.

$\therefore \quad R_1 = R_2 = 4R$

Since two resistors are in parallel,

$\therefore$ Effective resistance (R_e) is

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4R} + \frac{1}{4R} = \frac{2}{4R} = \frac{1}{2R}$$

$\therefore \quad R_e = 2R$

47. Let R be the resistance of one slab.

$\therefore$ Total resistance in figure (i) is

$R_1 = 2R$

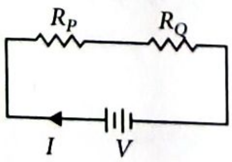
Total resistance in figure (ii) is

$R_2 = R/2$

Required ratio of the resistances $= R_1 : R_2$

$$= \frac{2R}{R/2} = 4:1$$

48. As per question $\frac{R_P}{R_Q} = \frac{1}{2}$



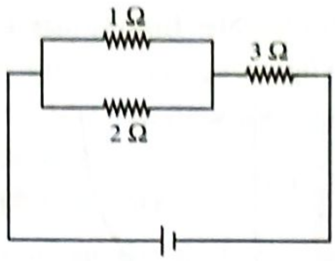
Power dissipation across a bulb

$P = I^2R$

Here current I is same for both the bulbs.

So, $\frac{P_P}{P_Q} = \frac{R_P}{R_Q} = \frac{1}{2}$.

49. (i) To get the equivalent resistance of $\frac{11}{3}\,\Omega$, the resistance of 1 Ω and 2 Ω must be in parallel and resistance of 3 Ω should be connected in series with the resulting resistance.



Equivalent resistance of the parallel combination of 1 Ω and 2 Ω is given by

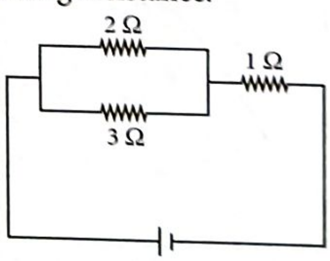
$$\frac{1}{R} = \frac{1}{1} + \frac{1}{2} \Rightarrow \frac{1}{R} = \frac{3}{2} \Rightarrow R = \frac{2}{3}$$

Now, resistance 3 Ω is connected in series to the resultant resistance. Here, the equivalent resistance is given by

$$R' = R + 3 \Rightarrow R' = \frac{2}{3} + 3$$

$\Rightarrow \quad R' = \frac{11}{3}\,\Omega$ (The required value of equivalent resistance)

(ii) To get the equivalent resistance of $\frac{11}{5}\,\Omega$, the resistance of 2 Ω and 3 Ω must be in parallel and resistance of 1 Ω should be connected in series with the resulting resistance.



Equivalent resistance of the parallel combination of 2 Ω and 3 Ω is

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{3} \Rightarrow \frac{1}{R} = \frac{5}{6} \Rightarrow R = \frac{6}{5}$$

Now, resistance 1 Ω is connected in series to the resultant resistance.

Here, the equivalent resistance is given by

$R' = R + 1$

$$\Rightarrow \quad R = \frac{6}{5} + 1 \Rightarrow R = \frac{11}{5}\,\Omega$$

(The required value of equivalent resistance).

50. $E_2 - E_1 = 8 - 4 = 4$ volt

Total resistance $= 0.5 + 1 + 4.5 + \frac{6 \times 3}{6+3} = 8\,\Omega$

$$I = \frac{4}{8} = 0.5\text{ A}$$

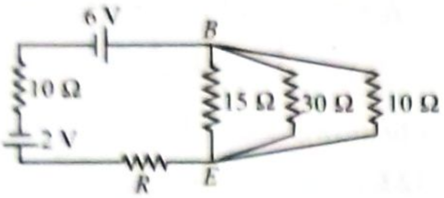
Current through 3 Ω resistor

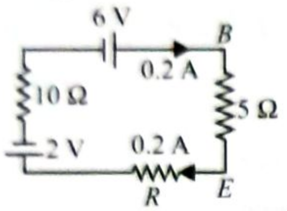
$$= \frac{6\times 0.5}{6+3} = 0.33 \text{ A}$$

Current through 6 Ω resistor

$$= \frac{3\times 0.5}{6+3} = \frac{1.5}{9} = 0.16 \text{ A}$$

51. The given circuit can be simplified





For BCD, equivalent resistance $R_1 = 5\,\Omega + 5\,\Omega = 10\,\Omega$

Across BE equivalent resistance R_2

$$\frac{1}{R_2} = \frac{1}{10} + \frac{1}{30} + \frac{1}{15} = \frac{3+1+2}{30} = \frac{6}{30} = \frac{1}{5}$$

$\Rightarrow \quad R_2 = 5\,\Omega$

Applying Kirchhoff's second law,

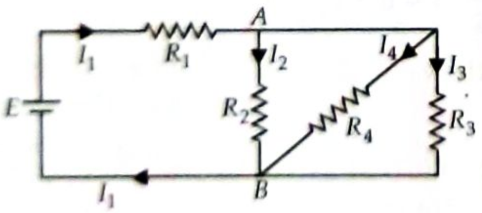
$6 - 2 = 5 \times 0.2 + R \times 0.2 + 10 \times 0.2$

$4 = 3 + 0.2\,R$ or $R = 5\,\Omega$

Potential difference $V_{BE} = I \times R_2 = 0.2 \times 5$

$\Rightarrow \quad V_{BE} = 1$ V

52.



From figure, R_2, R_3 and R_4 are connected in parallel.

$\therefore$ Effective resistance R_p

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{15} + \frac{1}{15} + \frac{1}{30} = \frac{5}{30}$$

$\Rightarrow \quad R_p = 6\,\Omega.$

Now, equivalent resistance of circuit,

$R = R_1 + R_p = 4 + 6 = 10\,\Omega$

Current $I_1 = \dfrac{10}{10} = 1$ A

Potential drop across $R_1 = I_1 R_1 = 1 \times 4 = 4$ V

Potential drop across all other resistances

$= 10 - 4 = 6$ V

Current through R_2 or R_3:

$$I_2 = \frac{6}{15}\text{ A},\ I_3 = \frac{6}{15}\text{ A} \Rightarrow I_2 = \frac{2}{5}\text{ A},\ I_3 = \frac{2}{5}\text{ A}$$

Current through R_4, $I_4 = \dfrac{6}{30}\text{ A} \Rightarrow I_4 = \dfrac{1}{5}$ A

53. (a) $R_{AB} = \dfrac{4\times 4}{4+4} = 2\,\Omega,$

$R_{BC} = 1\,\Omega,\ R_{CD} = \dfrac{12\times 6}{12+6} = 4\,\Omega$

Equivalent resistance of network

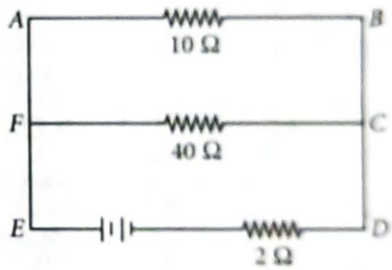
$R_{AD} = R_{AB} + R_{BC} + R_{CD} = 2 + 1 + 4 = 7\,\Omega$

(b) Current in circuit $I = \dfrac{E}{R+r} = \dfrac{16}{7+1} = 2$ A

$V_{AB} = R_{AB}\,I = 2 \times 2 = 4$ V

$V_{CD} = R_{CD}\,I = 4 \times 2 = 8$ V

54. Here simplified circuit is given as



Current delivered by the battery is $I^2 = \dfrac{P}{R}$

($\because$ Given power dissipated across 2 Ω is 200 W)

$I^2 = \dfrac{200}{2}$; $I^2 = 100 \Rightarrow I = 10$ A

$\therefore$ Current in branch AB is $I_{AB} = \dfrac{40\times 10}{40+10} = 8$ A

$\therefore$ Power dissipated across 5 Ω will be

$P = I_{AB}^2 \times 5\,\Omega = 8^2 \times 5 \Rightarrow P = 320$ W

55. Potential difference across a cell with internal resistance, r is $V = \varepsilon - Ir$.

As three cells are in series, so emf = 3ε and internal resistance = $3r$

$\therefore \quad V = 3\varepsilon - 3rI$

When $I = 0$ then $V = 6$ V, so $6 = 3\varepsilon - 0$ or $\varepsilon = 2$ V

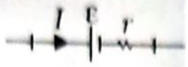
When $V = 0$ then $I = 1$ A, so $0 = 6 - 1 \times 3r$

or $\quad 3r = 6 \quad$ or $\quad r = 2\,\Omega$

56. We know the relation $V = \varepsilon - Ir$. The emf of a cell is greater than its terminal voltage because there may be some potential drop within the cell due to its small internal resistance offered by the electrolyte.

57. *Refer to answer 56.*

Note : When cell is charged the current goes into the positive terminal as shown in the figure. So potential difference across a cell, $V = \varepsilon + Ir$.



58. Here $\varepsilon_1 = \varepsilon$, $\varepsilon_2 = -2\varepsilon$ and $\varepsilon_3 = 5\varepsilon$,
$r_1 = r$, $r_2 = 2r$ and $r_3 = 3r$

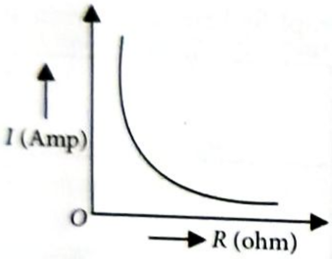
Equivalent emf of the cell is

$\varepsilon = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$
$= \varepsilon - 2\varepsilon + 5\varepsilon = 4\varepsilon$

Equivalent resistance $= r_1 + r_2 + r_3 + R$
$= r + 2r + 3r + R = 6r + R$

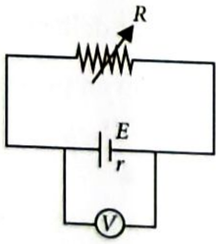
$\therefore$ Current $I = \dfrac{4\varepsilon}{6r + R}$

The graph for variation of current I with resistance R is shown below :



59. Terminal voltage 'V' of the cell is
$V = E - Ir$

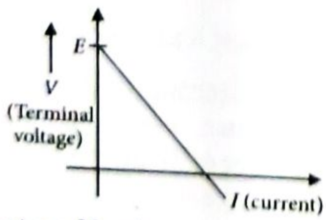
E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



So, $V = -Ir + E$

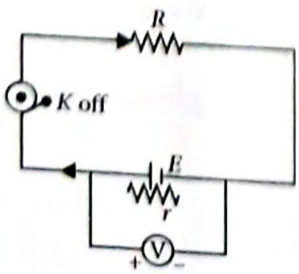
Comparing with the equation of a straight line $y = mx + c$, we get,
$y = V; x = I;$
$m = -r; c = E$

Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.

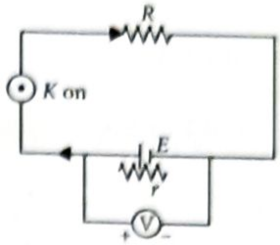


Emf of the cell = Intercept on V axis
Internal resistance = slope of line.

60. (a) Electromotive force of emf 'ε' of a cell is the potential difference across its terminals when no electric current is flowing through it or it is in an open circuit.



Terminal voltage V of a cell is the potential difference across its terminals when some electric current is flowing through it or it is in a closed circuit.



(b) *Refer to answer 59.*

61. $R_1 = 12\ \Omega$, $R_2 = 25\ \Omega$
$I_1 = 0.5$ A, $I_2 = 0.25$ A

For the 1st case

$r = \dfrac{\varepsilon}{I_1} - R_1 = \dfrac{\varepsilon}{0.5} - 12$

$r = \dfrac{\varepsilon - 6}{0.5}$ ...(i)

Now, for the 2nd case

$r = \dfrac{\varepsilon}{0.25} - 25$; $r = \dfrac{\varepsilon - 6.25}{0.25}$ ...(ii)

Compare the equation (i) and (ii), we get

$\dfrac{\varepsilon - 6}{0.5} = \dfrac{\varepsilon - 6.25}{0.25}$

$0.25\,\varepsilon - 1.5 = 0.5\,\varepsilon - 3.125$
$-0.25\,\varepsilon = -1.625$

$\varepsilon = \dfrac{1.625}{0.25}$; $\varepsilon = 6.5$ V

Putting the value of ε, $r = \dfrac{6.5 - 6}{0.5} = \dfrac{0.5}{0.5}$
$r = 1\ \Omega$

62. The current relating to corresponding situations are as follows :

(i) Without any external resistance $I_1 = \dfrac{E}{r}$

In this case, effective resistance of circuit is minimum so current is maximum.
Hence $I_1 = 4.2$ A.

(ii) With resistance R_1 only $I_2 = \dfrac{E}{r + R_1}$

In this case, effective resistance of circuit is more than situations (i) and (iv) but less than (iii). So $I_2 = 1.05$ A.

(iii) With R_1 and R_2 in series combination

$I_3 = \dfrac{E}{r + R_1 + R_2}$

In this case, effective resistance of circuit is maximum so current is minimum. Hence $I_3 = 0.42$ A.

(iv) $I_4 = \dfrac{E}{r + \dfrac{R_1 R_2}{R_1 + R_2}}$

In this case, the effective resistance is more than (i) but less than (ii) and (iii). So $I_4 = 1.4$ A.

63. Given $E = 10$ V, $r = 3\ \Omega$, $I = 0.5$ A

Total resistance of circuit

$$R + r = \frac{E}{I} = \frac{10}{0.5} = 20\ \Omega$$

(i) External resistance

$$R = 20 - r = 20 - 3 = 17\ \Omega$$

(ii) Terminal voltage

$$V = IR = 0.5 \times 17 = 8.5\ \text{V}$$

64. (i) The value of potential difference corresponding to zero current gives the emf of cell. This value is 1.4 Volt.

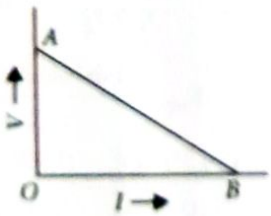
(ii) Maximum current is drawn form the cell when the terminal potential difference is zero. The current corresponding to zero value of terminal potential difference is 0.28 A. This is maximum value of current.

$$r = \frac{E}{I} = \frac{1.4}{0.28}\ \Omega;\ r = 5\ \Omega.$$

65. As, $V = \varepsilon - Ir \Rightarrow V = -Ir + \varepsilon$ ...(i)

$y = mx + C$ ...(ii)

Comparing (i) and (ii) we can say the graph between V and I is a straight line with a negative slope, as shown in figure.



For point A, $I = 0$

$V_A = \varepsilon$ = Intercept on the y-axis.

66. (a) $\because\ H = \dfrac{V^2}{R} t \Rightarrow \dfrac{H}{t} = \dfrac{V^2}{R}$

$\therefore\ \dfrac{H}{t} \propto V^2$

Given heat produce per second $\dfrac{H}{t}$, increases by a factor of 9.

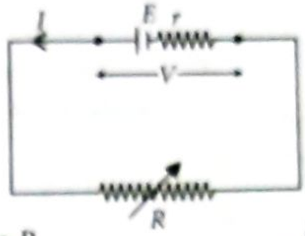
Hence, applied potential difference V increased by factor of 3.

(b) $I = \dfrac{E}{R + r} = \dfrac{12}{4 + 2} = \dfrac{12}{6} = 2$ A

$V = E - Ir = 12 - 2 \times 2 = 8$ V

67. Given situation is shown in figure

$$I = \frac{E}{r + R}$$



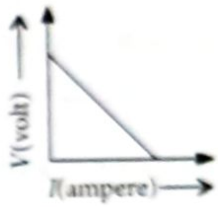
(i) V versus R.

Terminal voltage,

$V = E - Ir$

$$V = E - Ir = E - \frac{E}{r + R} r = \frac{ER}{r + R}$$

(ii) V versus I.



$V = E - Ir$

When $R = 4\ \Omega$,

then $I_1 = 1$ A

$\therefore\ \ 1 = \dfrac{E}{r + 4};\ r + 4 = E$ ...(i)

When $R = 9\ \Omega$, then $I = 0.5\ \text{A} = \dfrac{1}{2}$ A

$\therefore\ \ \dfrac{1}{2} = \dfrac{E}{r + 9} = \dfrac{r + 4}{r + 9}$ [Using eqn. (i)]

$r + 9 = 2r + 8,\ r = 1\ \Omega$

From eqn. (i)

emf, $E = 1 + 4 = 5$ V

68. Internal resistance of a cell depends upon

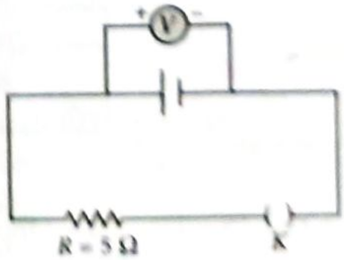
(i) surface area of each electrode.

(ii) distance between the two electrodes.

(iii) nature, temperature and concentration of electrolyte.

Let internal resistance of cell be r.

The circuit given in question can be redrawn as



Initially when K is open, voltmeter reads 2.2 V. i.e., emf of the cell, $\varepsilon = 2.2$ V

Later when K is closed, voltmeter reads 1.8 V which is actually the terminal potential difference, V. i.e., if I is the current flowing, then

$\varepsilon = I(R + r)$

$\Rightarrow \quad 2.2 = I(5 + r)$ ...(i)

and $\quad V = \varepsilon - Ir$

$1.8 = 2.2 - Ir$ ...(ii)

Solving (i) and (ii),

$I = 0.36$ A

Substituting in (ii)

$r = \frac{0.4}{0.36} \Rightarrow r = \frac{10}{9}\ \Omega$

69. The terminal potential difference of a cell is given by

$$V = \frac{\varepsilon R}{R + r}$$

Where ε is emf of the cell, r is internal resistance and R is an external resistance.

$$V = \frac{\varepsilon}{r/R + 1}$$

For resistance R_1, $V_1 = \frac{\varepsilon}{r/R_1 + 1}$

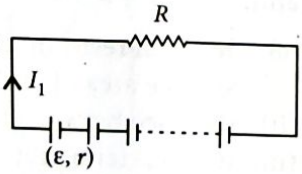
For resistance R_2, $V_2 = \frac{\varepsilon}{r/R_2 + 1}$

Since $R_1 > R_2$

$\therefore \quad V_1 > V_2$

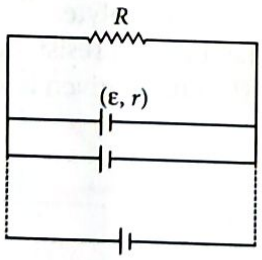
Hence terminal potential difference of the cell will be more when external resistor R_1 is connected to the cell.

70. For series combination



$$I_1 = \frac{n\varepsilon}{R + nr}$$

For parallel combination



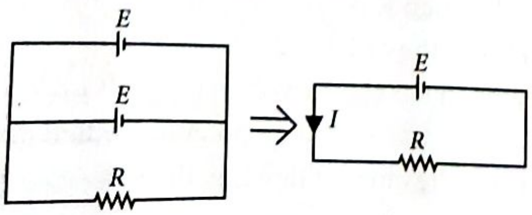
$$I_2 = \frac{\varepsilon}{R + \frac{r}{n}}$$

As per question,

$$I_1 = I_2 \Rightarrow \frac{n\varepsilon}{R + nr} = \frac{\varepsilon}{R + \frac{r}{n}}$$

$R + nr = nR + r$ or, $(n - 1)r = (n - 1)R$ or $r = R$ which is the required condition.

71.



So, current $I = \frac{E}{R}$

72. Equivalent emf and internal resistance of the combination of two cells connected in parallel combination is given as

$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} \text{ and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

Here $\varepsilon_1 = 2\varepsilon$, $\varepsilon_2 = \varepsilon$, $r_1 = 2r$ and $r_2 = r$

$$\therefore \quad \varepsilon_{eq} = \frac{2\varepsilon . r + \varepsilon . 2r}{2r + r}, r_{eq} = \frac{2r . r}{2r + r}$$

$$\varepsilon_{eq} = \frac{2\varepsilon r + 2\varepsilon r}{3r}, r_{eq} = \frac{2r^2}{3r}$$

$$\varepsilon_{eq} = \frac{4\varepsilon r}{3r}, r_{eq} = \frac{2}{3}r$$

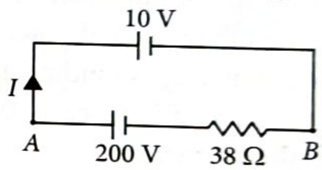
Therefore, $\varepsilon_{eq} = \frac{4}{3}\varepsilon$ and $r_{eq} = \frac{2}{3}r$.

73. As cells are connected in parallel so potential difference across terminals of each cell is same.

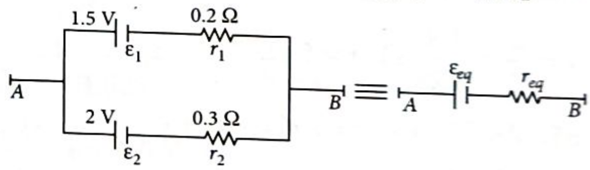
$200 - 38I = 10$

$38I = 200 - 10 = 190$

$I = \frac{190}{38} = 5$ A



74.



$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}, r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

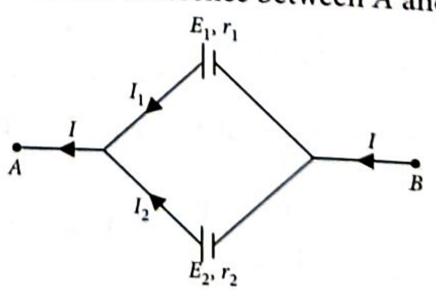
$$\therefore \quad \varepsilon_{eq} = \frac{1.5 \times 0.3 + 2 \times 0.2}{0.3 + 0.2}$$

$$= \frac{0.45 + 0.4}{0.5} = \frac{0.85}{0.5} = 1.7 \text{ V}$$

$$r_{eq} = \frac{0.2 \times 0.3}{0.2 + 0.3} = \frac{0.06}{0.5} = 0.12\ \Omega$$

75. Here, $I = I_1 + I_2$ ...(i)

Let V = Potential difference between A and B



For cell E_1,

$$V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}$$

Similarly, for cell E_2, $I_2 = \dfrac{E_2 - V}{r_2}$

Putting these values in equation (i)

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

or $\quad I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

or $\quad V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ ...(ii)

Comparing the above equation with the equivalent circuit of emf 'E_{eq}' and internal resistance 'r_{eq}' then,

$V = E_{eq} - Ir_{eq}$ ...(iii)

Then

(i) $E_{eq} = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ (ii) $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2}$

(iii) The potential difference between A and B

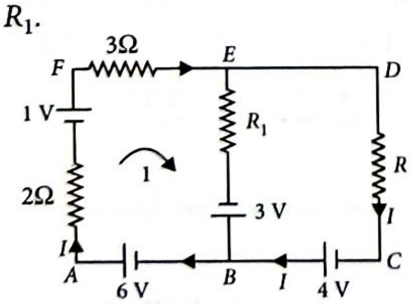
$V = E_{eq} - Ir_{eq}$

76. *Refer to answer 75.*

77. *Refer to answer 75.*

78. *Refer to answer 73.*

79. First we need to calculate R for no current through R_1.



By Kirchhoff' law,

$3I + RI + 2I = 1 + 4 + 6$

$5I + RI = 11$ ... (i)

Also, in loop (1),

$3I + 2I = 3 + 6 + 1$

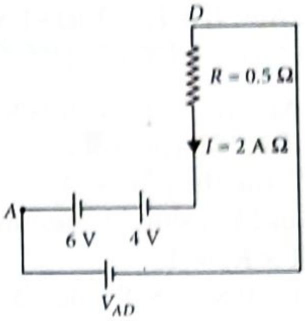
$5I = 10$ or $I = 2$ amp ... (ii)

Using in eqn. (i),

$10 + R \times 2 = 11$

$2R = 1$ or $R = 0.5\ \Omega$ ...(iii)

Now to determine the potential difference between A and D, we can assume a cell of required potential V_{AD} between two points.



On applying Kirchhoff's law,

$V_{AD} - 6 - 4 = -2 \times 0.5$

$V_{AD} - 10 = -1$

$V_{AD} = 9$ volt

80. Kirchhoff's first rule : The algebraic sum of all the current passing through a junction of an electric circuit is zero.

Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.

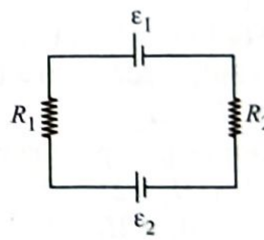
$I_1 + I_2 - I_3 + I_4 - I_5 = 0$

This rule is based on the principle of conservation of charge.

Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

Mathematically,

$\Sigma\varepsilon = \Sigma IR$



This is based on energy conservation principle

Using this rule,

$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$

81. In closed mesh $ABCD$

$I_1 r_1 + (I_1 + I_2) R = 12$

$2I_1 + 4(I_1 + I_2) = 12$

$2I_1 + 4I_1 + 4I_2 = 12$

$6I_1 + 4I_2 = 12$

$3I_1 + 2I_2 = 6$ ...(i)

In closed mesh $BDEF$

$(I_1 + I_2) R = 6$

$(I_1 + I_2) 4 = 6$

$2I_1 + 2I_2 = 3$ ...(ii)

On solving equations (i) and (ii), we get

$I_1 = 3$

Putting the value of I_1 in equation (i)

$3I_1 + 2I_2 = 6$

$3 \times 3 + 2I_2 = 6$

$I_2 = -1.5$

Now, $I_1 + I_2 = 3 + (-1.5) = 1.5$ A

$P = (I_1 + I_2)^2 R = (1.5)^2 \times 4 = 2.25 \times 4 = 9$ watt.

82. (i) To measure current upto 5 A, the shunt S should have a value, such that for 5 A input current through system , 4 A should pass through shunt S and 1 A should pass through given ammeter.

$1 \times R_A = 4S$

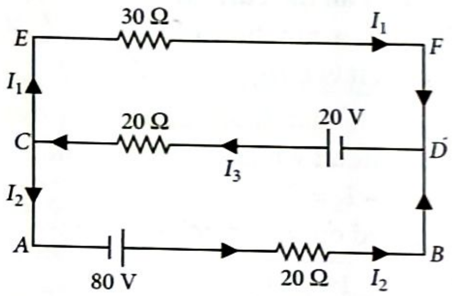
$1 \times 0.8 = 4S; S = 0.2\ \Omega$

Thus, the shunt resistance is 0.2 Ω.

(ii) Combined resistance of the ammeter and the shunt,

$$R = \frac{0.8S}{0.8+S} = \frac{0.8 \times 0.2}{0.8+0.2} = \frac{0.16}{1} = 0.16\ \Omega$$

83.



Applying Kirchhoff 1st law.

$I_3 = I_1 + I_2$ (at C) ...(i)

Applying Kirchhoff's loop rule to $CDFEC$

$-30I_1 + 20 - 20I_3 = 0$

$3I_1 + 2I_3 = 2$ ...(ii)

For loop $ABFEA$

$-30I_1 + 20I_2 - 80 = 0$

$-3I_1 + 2I_2 = 8$ ...(iii)

from eq. (i) put the value of I_3 in eq. (ii)

$3I_1 + 2I_1 + 2I_2 = 2$

$5I_1 + 2I_2 = 2$ ...(iv)

$-3I_1 + 2I_2 = 8$

$8I_1 = -6$

$I_1 = -3/4$ A

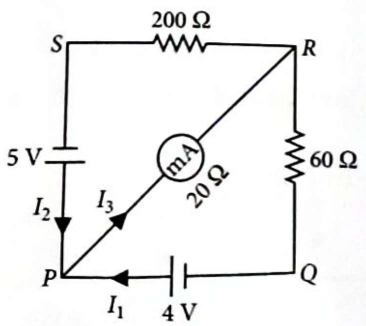
Put I_1 in eq. (iv)

$-5 \times 3/4 + 2I_2 = 2 \Rightarrow I_2 = \frac{23}{8}$ A

from eq. (i)

$$I_3 = \frac{-3}{4} + \frac{23}{8} = \frac{-6+23}{8} = \frac{17}{8}\text{ A}$$

84.



Applying Kirchhoff's 2nd law to the loop $PRSP$

$-I_3 \times 20 - I_2 \times 200 + 5 = 0$

$4I_3 + 40I_2 = 1$ ...(i)

for loop $PRQP$,

$-20I_3 - 60I_1 + 4 = 0$

$5I_3 + 15I_1 = 1$ ...(ii)

Applying Kirchhoff's 1st law

$I_3 = I_1 + I_2$ ...(iii)

from eq. (i) and (iii) we have,

$4I_1 + 44I_2 = 1$

from eq. (ii) and (iii)

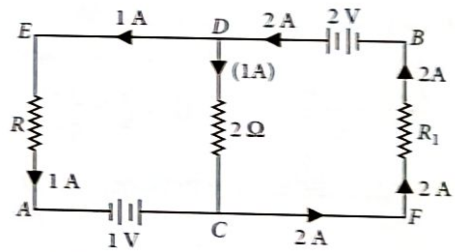
$20I_1 + 5I_2 = 1$

On solving we get

$$I_3 = \frac{11}{172}\text{ A} = \frac{11000}{172}\text{ mA}$$

$$I_2 = \frac{4000}{215}\text{ mA}, I_1 = \frac{39000}{860}\text{ mA}$$

85.



Using KCL at point D

$I_{DC} + 1 = 2$

$I_{DC} = 1$A

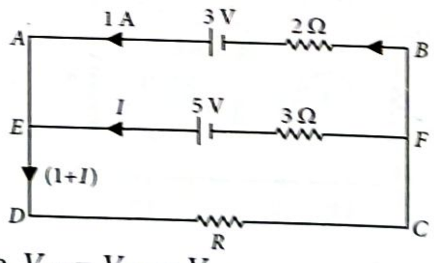
Along $ACDB$

$V_A + 1 + 1 \times 2 - 2 = V_B$

But $V_A = 0$

$V_B = 1 + 2 - 2 = 1$ V

86.



Here, $V_{AB} = V_{CD} = V_{EF}$

$V_{AB} = V_{CD} \Rightarrow$ Voltage drop across $R = 3 - 1 \times 2 = 1$V

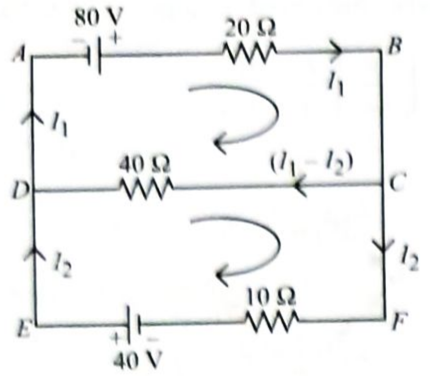
Now, V_{EF} - $V_{CD} \Rightarrow 5 - 3I = 1 \Rightarrow I = \frac{4}{3}$A.

87. Applying KVL in closed loop $ABCDA$

$-80 + 20I_1 + 40(I_1 - I_2) = 0$

$20I_1 + 40I_1 - 40I_2 = 80$

$60I_1 - 40I_2 = 80$



$3I_1 - 2I_2 = 4$ ...(i)

Applying KVL in closed loop *DCFED*

$-40(I_1 - I_2) + 10I_2 - 40 = 0$

$-40I_1 + 40I_2 + 10I_2 - 40 = 0$

$-40I_1 + 50I_2 = 40$

or $-4I_1 + 5I_2 = 4$ ...(ii)

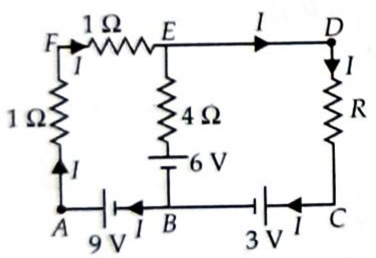
From (i) and (ii)

$I_2 = 4$ A and $I_1 = 4$ A

$\therefore$ Current flows through 40 Ω $= I_1 - I_2 = 0$ A

Current flows through 20 Ω = 4 A

88. As no current flows through 4 Ω, the current in various branches as shown in the figure.



Applying Kirchhoff's loop rule to the closed loop *AFEBA*, we get

$-I - I - 4 \times 0 - 6 + 9 = 0$ or $9 - 6 - 2I = 0$ or $2I = 3$

or $I = \frac{3}{2}$ A ...(i)

Again, applying Kirchhoff's loop rule to the closed loop *BEDCB*, we get

$6 + 4 \times 0 - IR - 3 = 0$ or $IR = 3$

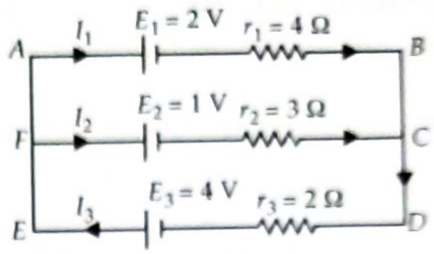
$R = \frac{3}{I} = 3 \times \frac{2}{3} = 2\,\Omega$ (Using (i))

Potential difference between *A* and *D* = Potential difference between *A* and *E*

$\therefore \quad V_{AD} = 2I = 2 \times \frac{3}{2} = 3$ V

89. (a) *Refer to answer 80.*

(b) To find I_1, I_2, I_3 in following diagram.



For loop *ABCFA*, $E_1 + I_1r_1 - I_2r_2 - E_2 = 0$

$\Rightarrow \quad 2 + 4I_1 - 3I_2 - 1 = 0$

$\Rightarrow \quad 4I_1 - 3I_2 + 1 = 0$ ...(i)

Using loop *FCDEF*

$E_2 + I_2r_2 + I_3r_3 - E_3 = 0$

$\Rightarrow \quad 1 + 3I_2 + 2I_3 - 4 = 0$

$\Rightarrow \quad 3I_2 + 2I_3 - 3 = 0$ ...(ii)

Also using junction rule $I_3 = I_1 + I_2$ ...(iii)

Using (ii) and (iii)

$3I_2 + 2I_1 + 2I_2 - 3 = 0$

$\Rightarrow \quad 2I_1 + 5I_2 - 3 = 0$ ...(iv)

Solving (i) and (iv)

$$4I_1 - 3I_2 + 1 = 0$$
$$-2 \times (2I_1 + 5I_2 - 3) = 0$$
$$0 - 13I_2 + 7 = 0$$

$\Rightarrow \quad I_2 = \frac{7}{13}$ A

Substituting in (i)

$4I_1 - 3 \times \frac{7}{13} + 1 = 0$

$4I_1 = \frac{8}{13} \Rightarrow I_1 = \frac{2}{13}$ A

$\Rightarrow \quad I_3 = I_1 + I_2 = \frac{9}{13}$ A

90. (a) *Refer to answer 80.*

(b) The network is not reducible to a simple series and parallel combinations of resistors. There is however, a clear symmetry in the problem which we can exploit to obtain the equivalent resistance of the network. The paths *AA'*, *AD* and *AB* are obviously symmetrically placed in the network. Thus, the current in each must be the same, say, *I*. Further at the corners *A'*, *B* and *D*, the incoming current *I* must split equally into the two outgoing branches. In this manner, the current, in all the 12 edges of the cube are easily written down in terms of *I*, using Kirchhoff's first rule and the symmetry

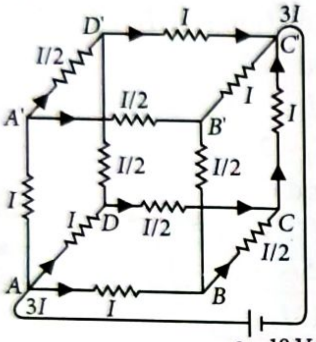
in the problem. Next take a closed loop, say, $ABCC'EA$, and apply Kirchhoff's second rule :
$-IR - (1/2)\,IR - IR + \varepsilon = 0$
Where R is the resistance of each edge and ε the emf of battery. Thus, $\varepsilon = \frac{5}{2}IR$

The equivalent resistance R_{eq} of the network is

$$R_{eq} = \frac{\varepsilon}{3I} = \frac{5}{6}R$$

For $R = 1\ \Omega$, $R_{eq} = (5/6)/\Omega$ and for $\varepsilon = 10$ V, the total current (= $3I$) in the network is $3I = 10\ \text{V}/(5/6)\ \Omega = 12$ A. *i.e.*, $I = 4$ A

The current flowing in each edge can now be read off from the figure.

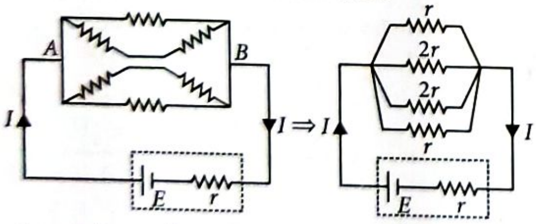


(i) The equivalent resistance of the network is $\frac{5}{6}\ \Omega$.

(ii) The total current in the network is 12 A.

91. (i) *Refer to answer 80.*

(ii) Circuit can be redrawn as



For net resistance between point A and B.
Here, r, $2r$, $2r$ and r are in parallel.

So, $\frac{1}{R_{AB}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{2r} + \frac{1}{2r}$

$\frac{1}{R_{AB}} = \frac{3}{r}$ or, $R_{AB} = \frac{r}{3}$

Net resistance of the circuit,

$$R = r + R_{AB} = r + \frac{r}{3} = \frac{4r}{3}$$

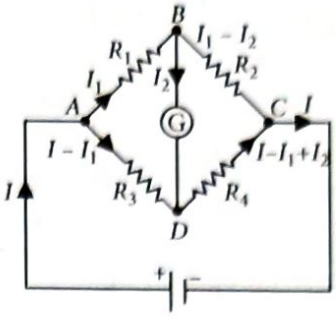
(a) Current drawn from the cell

$$I = \frac{E}{R} = \frac{E}{(4r/3)} = \frac{3E}{4r}$$

(b) Power consumed in network, $P = I^2 R_{AB}$

$$\therefore \quad P = \left(\frac{3E}{4r}\right)^2 \frac{r}{3} = \frac{3E^2}{16r}$$

92.



Consider loop $ABDA$

$I_1R_1 + I_2G - (I - I_1)\,R_3 = 0$

$I_1(R_1 + R_3) + I_2G - IR_3 = 0$ ...(i)

Consider loop $BCDB$

$(I_1 - I_2)R_2 - (I - I_1 + I_2)R_4 - I_2G = 0$

$I_1(R_2 + R_4) - I_2(R_2 + R_4 + G) - IR_4 = 0$ ...(ii)

When bridge is balanced, B and D are at same potential *i.e.*, $I_2 = 0$. From equations (i) and (ii), we get

$$\frac{R_1 + R_3}{R_2 + R_4} = \frac{R_3}{R_4}$$

$R_1R_4 + R_3R_4 = R_3R_4 + R_2R_3$

$R_1R_4 = R_2R_3$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

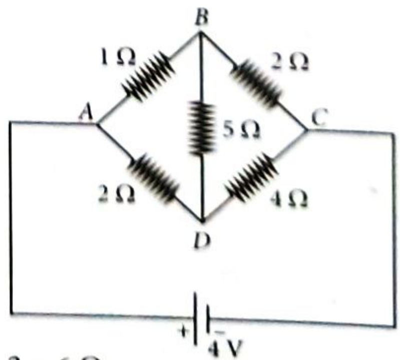
93. Since the condition $\frac{P}{Q} = \frac{R}{S}$ is satisfied, it is a balanced bridge.

The equivalent Wheatstone bridge for the given combination is shown in figure.

The resistance of arm ABC,

$R_{S_1} = 2 + 1 = 3\ \Omega$

Also, the resistance of arm ADC,



$R_{S_2} = 4 + 2 = 6\ \Omega$

Equivalent resistance

$$R_{eq} = \frac{R_{S_1} \times R_{S_2}}{R_{S_1} + R_{S_2}}$$

$$= \frac{3 \times 6}{3+6} = \frac{18}{9} = 2\ \Omega$$

Current drawn from the battery

$$I = \frac{V}{R_{eq}} = \frac{4}{2} \therefore I = 2\ \text{A}.$$

94. In case of balanced Wheatstone bridge, no current flows through the resistor 10 Ω between points *B* and *C*.

The resistance of arm *ACD*, $R_{S_1} = 10 + 20 = 30\ \Omega$

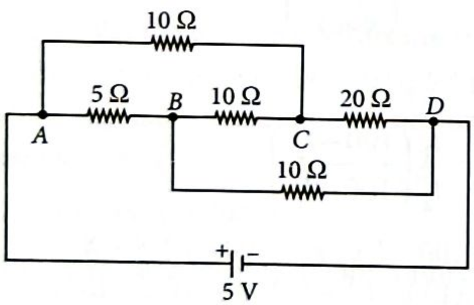
The resistance of arm *ABD*, $R_{S_2} = 5 + 10 = 15\ \Omega$

Equivalent resistance $R_{eq} = \dfrac{R_{S_1} \times R_{S_2}}{R_{S_1} + R_{S_2}}$

$$= \frac{30 \times 15}{30+15} = \frac{30 \times 15}{45} = 10\ \Omega$$

Current drawn from the source,

$$I = \frac{V}{R_{eq}} = \frac{5}{10} = \frac{1}{2}\text{A} = 0.5\ \text{A}$$



95. (a) *Refer to answer 80.*

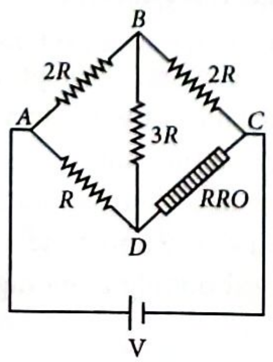
(b) *Refer to answer 92.*

96. *Refer to answer 92.*

Let the carbon resistor be *S* in the given wheatstone bridge, we have

$$\frac{2R}{R} = \frac{2R}{S}$$

$$\Rightarrow 1 = \frac{R}{S}$$

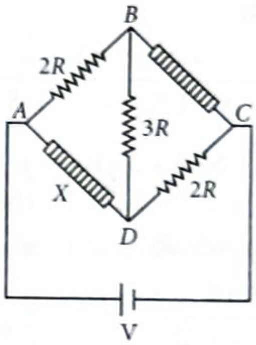


$\Rightarrow$ $R = S$ = resistance of carbon resistor

$\therefore$ $R = S = 22 \times 10^3\ \Omega = 22\ \text{k}\Omega$

When the resistance are interchanged, the bridge will be a balanced if

$$\frac{2R}{X} = \frac{22 \times 10^3}{2 \times 22 \times 10^3} = \frac{1}{2}$$



$\therefore$ $X = 4R = 4 \times 22\ \text{k}\Omega = 88\ \text{k}\Omega$

Thus, the sequence of colour will be grey, grey orange.

97. The value of balancing length would remain same, there will be no effect of changing the radius of the wire. Because balancing length is independent of radius of the wire, it only depends on the length ratio.

$$\frac{R_1}{R_2} = \frac{x}{100 - x}$$

98. Here $l_1 = 40$ cm

$$\because \quad \frac{R}{S} = \frac{l_1}{100 - l_1} \Rightarrow \frac{R}{S} = \frac{40}{100 - 40}$$

$$\Rightarrow \quad \frac{R}{S} = \frac{40}{60} \Rightarrow \frac{R}{S} = \frac{2}{3} \quad \therefore\ R : S = 2 : 3.$$

99. The shifting of zero at the scale of different points as well as the stray resistance give rise to the end error in meter bridge wire. The end error in meter bridge occur due to following reasons :

(i) The zero mark of the scale provided along the wire may not start from the position where the bridge wire leave the copper strip and 100 cm mark of the scale may not end at position where the wire touches the copper strip.

(ii) The resistance of copper wires and copper strips of the meter bridge has not been taken into account.

In first case, $\dfrac{R}{S} = \dfrac{l_1}{(100 - l_1)} \Rightarrow R = \dfrac{Sl_1}{(100 - l_1)}$ ...(i)

In second case, $\dfrac{R}{\left(\dfrac{RS}{R+S}\right)} = \dfrac{1.5l_1}{(100-1.5l_1)}$

or $\quad R = \dfrac{1.5l_1}{(100-1.5l_1)} \times \dfrac{RS}{(R+S)}$ ...(ii)

From (i) and (ii)

$$\frac{Sl_1}{(100-l_1)} = \frac{1.5l_1 \times RS}{(100-1.5l_1)\times(R+S)}$$

$(100 - 1.5l_1)(R + S) = 1.5\,(100 - l_1)R$

$100R + 100S - 1.5l_1R - 1.5l_1S = 150R - 1.5l_1R$

$(100 - 1.5l_1) \times S = 50R$

or, $\quad S = \dfrac{50R}{(100-1.5l_1)}$

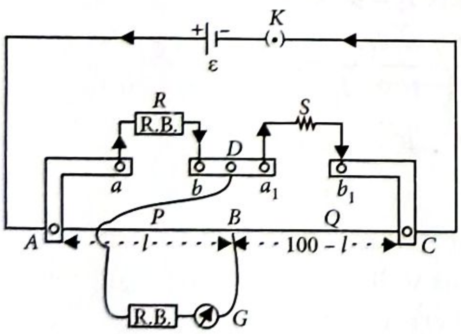
Given, $R = 5\ \Omega$

$\therefore \quad S = \dfrac{250}{(100-1.5l_1)}$

100. Metre bridge : It is the simplest practical application of the Wheatstone bridge that is used to measure an unknown resistance.

Principle : Its working is based on the principle of Wheatstone bridge.

When the bridge is balanced, $\dfrac{P}{Q} = \dfrac{R}{S}$



Measurement of unknown resistance by a metre bridge.

Working : After taking out a suitable resistance R from the resistance box, the jockey is moved along the wire AC till there is no deflection in the galvanometer. This is the balanced condition of the Wheatstone bridge. If P and Q are the resistance of the parts AB and BC of the wire, then for the balanced condition of the bridge, we have

$$\frac{P}{Q} = \frac{R}{S}$$

Let total length of wire $AC = 100$ cm and $AB = l$ cm, then $BC = (100 - l)$ cm. Since the bridge wire is of uniform cross-section, therefore,

resistance of wire $\propto$ length of wire

or $\quad \dfrac{P}{Q} = \dfrac{\text{resistance of } AB}{\text{resistance of } BC} = \dfrac{\sigma l}{\sigma(100-l)} = \dfrac{l}{100-l}$

where σ is the resistance per unit length of the wire.

Hence, $\dfrac{R}{S} = \dfrac{l}{100-l}$ or $S = \dfrac{R(100-l)}{l}$

Knowing l and R, unknown resistance S can be determined.

101. (a) The metre bridge works on the principle of balanced condition of Wheatstone bridge.

(b) According to the problem,

$\dfrac{R}{S} = \dfrac{l_1}{100-l_1}$ ...(i)

Now, when unknown resistance X is connected in parallel with resistance S, the effective resistance of this pair becomes $\dfrac{SX}{S+X}$

$\therefore$ we get $\dfrac{R}{\left(\dfrac{SX}{S+X}\right)} = \dfrac{l_2}{100-l_2}$ ...(ii)

Dividing eq. (i) by (ii), we get

$$\frac{X}{S+X} = \frac{l_1}{l_2}\left(\frac{100-l_2}{100-l_1}\right)$$

or $\quad l_2(100 - l_1)X = l_1(100 - l_2)(S + X)$

or $\quad \{l_2(100 - l_1) - l_1(100 - l_2)\}X = l_1(100 - l_2)S$

or $\quad (l_2 - l_1) \times (100X) = l_1(100 - l_2)S$

or $\quad X = \dfrac{l_1(100-l_2)}{100(l_2-l_1)}S$

where l_1 and l_2 are in centimeters.

102. *Refer to answer 100.*

Necessary precautions to minimize error in the result :

(i) The current must be kept at low value. Otherwise, resistance of wire changes on getting heated and affected the values.

(ii) The current should not be passed continuously for a very long time.

(iii) The jockey should not be dragged along the wire.

103. (a) The resistivity of a copper wire is very low. Also, the connections are thick, so that the area is quite large and hence the resistance of the wires is almost negligible.

(b) It is preferred to obtain the balance point in the middle of the meter bridge wire because it improves the sensitivity of the meter bridge and minimum error due to resistance of copper strips.

(c) Constantan is used for meter bridge wire because its temperature coefficient of resistance is almost negligible due to which the resistance of the wire does not change with increase in temperature of the wire due to flow of current.

104. Working principle of a meter bridge is the wheatstone bridge condition. The value of R and X were doubled and then interchanged. Hence the new position of balance point remain same.

$AJ = 40$ cm

From the principle of Wheatstone bridge,

$$\frac{R}{X} = \frac{40}{100-40}$$

$$X = R\frac{60}{40} = \frac{3R}{2}$$

When, the galvanometer and cell are interchanged, the condition for a balance bridge is still satisfied. Therefore the galvanometer will not show any deflection.

105. *Refer to answer 104.*

106. When resistances R and S are connected then balance point is found at a distance 40 cm from the zero

$$\frac{R}{S} = \frac{40}{100-40}$$

$$\frac{R}{S} = \frac{40}{60} \Rightarrow \frac{R}{S} = \frac{2}{3} \quad \text{....(i)}$$

When a resistance of 12 Ω is connected in parallel with S then total resistance in the right hand gap is

$$S_1 = \frac{12S}{S+12} \quad \text{...(ii)}$$

$$\left[\because \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R = \frac{R_1R_2}{R_1+R_2}\right]$$

Since balance point is obtained at a distance 50 cm form the zero.

$$\therefore \quad \frac{R}{S_1} = \frac{50}{100-50} \Rightarrow \frac{R}{S_1} = \frac{50}{50}$$

$$\therefore \quad \frac{R}{S_1} = 1 \quad \text{...(iii)}$$

Dividing (i) by (iii), we get

$$\frac{\frac{R}{S}}{\frac{R}{S_1}} = \frac{\frac{2}{3}}{1} \Rightarrow \frac{R}{S}\cdot\frac{S_1}{R} = \frac{2}{3}$$

$$\Rightarrow \quad \frac{S_1}{S} = \frac{2}{3} \Rightarrow S_1 = \frac{2}{3}S$$

Putting the value of S_1 in (ii), we get

$$\frac{2}{3}S = \frac{12S}{S+12} \Rightarrow \frac{2}{3} = \frac{12}{S+12}$$

$$\Rightarrow \quad 2S + 24 = 36 \Rightarrow 2S = 12 \;\therefore\; S = 6\,\Omega$$

Putting the value of S in (i), we get

$$\frac{R}{6} = \frac{2}{3} \Rightarrow R = \frac{2}{3}\times 6 = 4\,\Omega$$

$$\therefore \quad R = 4\,\Omega \text{ and } S = 6\,\Omega$$

107. Case - I : $\frac{R_1}{R_2} = \frac{40}{(100-40)} = \frac{40}{60} = \frac{2}{3}$

$$\frac{R_1}{R_2} = \frac{2}{3} \quad \text{...(i)}$$

Case - II : $\frac{R_1+10}{R_2} = \frac{60}{(100-60)} = \frac{60}{40} = \frac{3}{2}$

$$\frac{R_1+10}{R_2} = \frac{3}{2} \quad \text{...(ii)}$$

From eqn (i) and (ii), we get

$$\frac{2}{3} + \frac{10}{R_2} = \frac{3}{2}$$

$R_2 = 12\,\Omega$

From equation (i) $\frac{R_1}{12} = \frac{2}{3}$; $R_1 = 8\,\Omega$

108. (a) *Refer to answer 100.*

(b) *Refer to answer 104.*

(c) The bridge is most sensitive when null point is somewhere near the middle point of the wire. This is due to end resistance. Because of this reason it is important to obtain the balance point near the mid-point of the wire.

109. *Refer to answer 100.*

110. Working : When a constant current flows through a wire of uniform thickness, the potential difference between its two points is directly proportional to the length of the wire between these two points.

$V \propto l \Rightarrow V = Kl$, where K is potential gradient.

111. $\varepsilon = I(R + r)$ and $V = IR$

$$\therefore \quad \frac{\varepsilon}{V} = \frac{R + r}{R}$$

We get, $r = \left(\frac{\varepsilon}{V} - 1\right)R$

112. Here $l_1 = 350$ cm, $l_2 = 300$ cm, $R = 9\ \Omega$, $r = ?$

Internal resistance of the cell, $r = \left(\frac{l_1}{l_2} - 1\right)R$

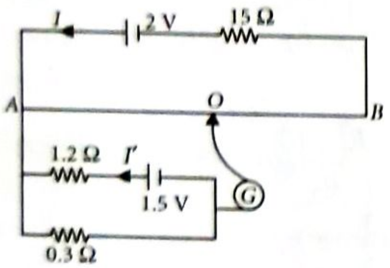
$$r = \left(\frac{350}{300} - 1\right)9 = \frac{50}{300} \times 9 = \frac{3}{2}\ \Omega$$

113. (i) *Refer to answer 110.*

(ii) Here $AB = 1$ m, $R_{AB} = 10\ \Omega$,

Potential gradient, $k = ?$, $AO = l = ?$

Current passing through AB,



$$I = \frac{2}{15 + R_{AB}} = \frac{2}{15 + 10} = \frac{2}{25}\ \text{A}$$

$$V_{AB} = I \times R_{AB} = \frac{2}{25} \times 10 = \frac{4}{5}\ \text{V}$$

$$\therefore \quad k = \frac{V_{AB}}{AB} = \frac{4}{5}\ \text{V m}^{-1}$$

Current in the external circuit,

$$I' = \frac{1.5}{1.2 + 0.3} = \frac{1.5}{1.5} = 1\ \text{A}$$

For no deflection in galvanometer,

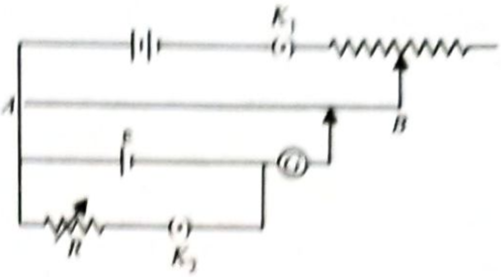
Potential difference across $AO = 1.5 - 1.2\,I'$

$\Rightarrow \quad k(l) = 1.5 - 1.2 \times I'$

$$\Rightarrow \quad \frac{4}{5}l = 0.3 \text{ or, } l = \frac{0.3 \times 5}{4} = 0.375\ \text{m}$$

$\therefore \quad l = 37.5$ cm

114. Internal resistance by potentiometer



Initially key K_2 is off

Then at balancing length l_1

$\varepsilon = Kl_1$ ...(i)

Now key K_2 is made on.

Then at balancing length l_2

$V = Kl_2$ ...(ii)

So, $\frac{\varepsilon}{V} = \frac{l_1}{l_2}$ ...(iii)

$$\text{Also, } \frac{\varepsilon}{V} = \frac{\varepsilon}{\varepsilon - Ir} = \frac{\varepsilon}{\varepsilon - \frac{\varepsilon}{(R + r)}r} = \frac{R + r}{R} = 1 + \frac{r}{R}$$

$$r = \left(\frac{\varepsilon}{V} - 1\right)R$$

So, $r = \left(\frac{l_1}{l_2} - 1\right)R$ [Using (iii)]

115. (i) By increasing resistance R, the current through AB decreases, so potential gradient decreases. Hence a greater length of wire would be needed for balancing the same potential difference. So the null point would shift towards B.

(ii) By decreasing resistance S, the current through AB remains the same, potential gradient does not change. As K_2 is open so there is no effect of S on null point.

116. (a) (i) If R_1 is decreased then current in the given circuit is increased. Hence potential gradient across wire AB will be increased.

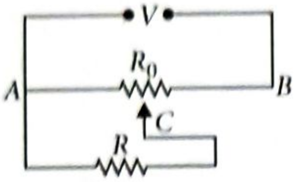
So jockey J will shift towards point A *i.e.*, balancing length will be decreased.

(ii) If R_2 is increased, *emf* of the cell will not be affected. Hence balancing length will not be affected.

(b) When a potentiometer is used to measure the potential difference in a branch, it does not draw any current from the circuit. Hence it gives accurate reading.

117. While the slide is in the middle of the potentiometer only half of its resistance $(R_0/2)$

will be between the points A and C. Hence, the total resistance between A and C, R_1, will be given by the following expression,



$$\frac{1}{R_1}=\frac{1}{R}+\frac{1}{(R_0/2)}$$

$$R_1=\frac{R_0R}{R_0+2R}$$

The total resistance between A and C will be sum of resistance between A and C and C and B, *i.e.*, $R_1 + R_0/2$

∴ The current flowing through the potentiometer will be

$$I=\frac{V}{R_1+R_0/2}=\frac{2V}{2R_1+R_0}$$

The voltage V_1 taken from the potentiometer will be the product of current I and resistance R_1,

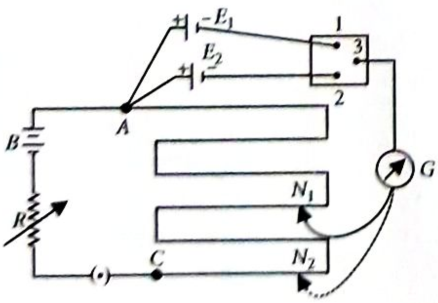
$$V_1=IR_1=\left(\frac{2V}{2R_1+R_0}\right)\times R_1$$

Substituting for R_1, we have

$$V_1=\frac{2V}{2\left(\frac{R_0\times R}{R_0+2R}\right)+R_0}\times\frac{R_0\times R}{R_0+2R}$$

$$V_1=\frac{2VR}{2R+R_0+2R}\quad\text{or}\quad V_1=\frac{2VR}{R_0+4R}$$

118. Working principle of potentiometer : When a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.



Application of potentiometer for comparing emf's of two cells : The given figure shows an application of the potentiometer to compare the emf of two cells of emf E_1 and E_2. E_1, E_2 are the emfs of the two cells and 1, 2, 3 form a two way key.

When 1 and 3 are connected, E_1 is connected to the galvanometer (G).

Jokey is moved to N_1, which is at a distance l_1 from A, to find the balancing length.

Applying loop rule to AN_1G31A,

$\phi l_1 + 0 - E_1 = 0$ ...(i)

Where, ϕ is the potential drop per unit length.

Similarly, for E_2 balanced against $l_2(AN_2)$,

$\phi l_2 + 0 - E_2 = 0$ ...(ii)

From equation (i) and (ii)

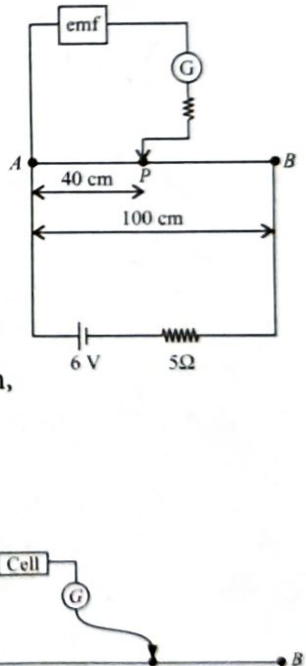
$$\frac{E_1}{E_2}=\frac{l_1}{l_2}\qquad\text{...(iii)}$$

Thus we can compare the emfs of any two sources. Generally, one of the cells is chosen as a standard cell whose emf is known to a high degree of accuracy. The emf of the other cell is then calculated from equation (iii).

119. Net resistance of the circuit,

$R = (R_{AB} + 5) = 10 + 5 = 15\ \Omega$

Current flowing in the circuit,



$I=\frac{V}{R}=\frac{6}{15}$ A

Potential drop across

$AB = IR_{AB}$

$=\frac{6}{15}\times 10=4\text{V}$

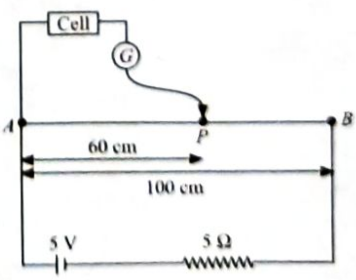
e.m.f. of primary cell,

$\varepsilon=\frac{l}{L}V_{AB}$

Here, $l = 40$ cm, $L = 100$ cm, $V_{AB} = 4$ V

So, $\varepsilon=\frac{40}{100}\times 4=1.6$ V

120. From the figure :



Total resistance of the circuit,

$R = (R_{AB} + 5)\ \Omega = 20\ \Omega$

Current in the circuit,

$I = V/R = 5/20 = 0.25$ V

∴ Voltage across AB,

$V_{AB} = I.R_{AB} = 3.75$ V

The emf of the cell connected as above is given by:

$$\varepsilon=\frac{V_{AB}}{L}l$$

Here, $l = 60$ cm (balance point)

$L = 1$ m $= 100$ cm (total length of the wire)

$\therefore \quad \varepsilon = \frac{3.75 \times 60}{100} = 2.25 \text{ V}$

121. (a) Principle of potentiometer : The potential drop across the length of a steady current carrying wire of uniform cross-section is proportional to the length of the wire.

(i) We use a long wire to have a lower value of potential gradient *i.e.*, a lower "least count" or greater sensitivity of the potentiometer.

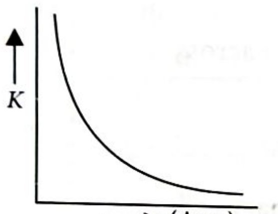
(ii) The area of cross section has to be uniform to get a uniform wire as per the principle of the potentiometer.

(iii) The emf of the driving cell has to be greater than the emf of the primary cells as otherwise, no balance point would be obtained.

(b) Potential gradient, $K = \frac{V}{L} = \frac{IR}{L} = \frac{IP}{A}$

KA = constant

$\therefore$ The required graph is shown in the figure



122. Principle of potentiometer : When a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

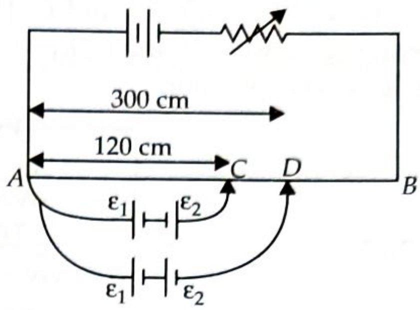
Factors on which sensitivity of potentiometer depends are :

(a) Resistance of the wire, (b) Number of the turns in the wire, and (c) Increasing the length of the wire.

(i) When resistance R is increased, the current through potentiometer wire AB will decrease, so potential difference across AX will decrease, so balance point X will shift towards B.

(ii) When resistance S is increased, keeping R constant there is no change in balance point because there is no current in the secondary circuit.

123. (i)



Let ϕ V cm^{-1} be potential gradient of the wire.

Applying Kirchhoff's loop rule to the closed loop ACA, we get

$\phi(120) = \varepsilon_1 - \varepsilon_2$ ...(i)

Again, applying Kirchhoff's loop rule to the closed loop ADA, we get

$\phi(300) = \varepsilon_1 + \varepsilon_2$ ...(ii)

Divide (i) by (ii), we get

$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} = \frac{120}{300} = \frac{2}{5}$$

$5\varepsilon_1 - 5\varepsilon_2 = 2\varepsilon_1 + 2\varepsilon_2$ or $3\varepsilon_1 = 7\varepsilon_2$

$\frac{\varepsilon_1}{\varepsilon_2} = \frac{7}{3}$ ...(iii)

(ii) Let the position of null point for the cell ε_1 is l_3.

$\therefore \quad \varepsilon_1 = \phi l_3$ ...(iv)

Divide (i) by (iv), we get

$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1} = \frac{120}{l_3} \quad \text{or} \quad 1 - \frac{\varepsilon_2}{\varepsilon_1} = \frac{120}{l_3}$$

$1 - \frac{3}{7} = \frac{120}{l_3}$ (Using (iii))

$\frac{4}{7} = \frac{120}{l_3}$ or $l_3 = 210$ cm

Sensitivity of a potentiometer is increased by increasing the length of the potentiometer wire.

124. (a) *Refer to answer 110.*

(b) *Refer to answer 114.*

125. *Refer to answers 110 and 114.*

126. (i) As per the figure,

Total current through the wire AB is given by

$$I = \frac{E}{R + r} = \frac{2}{R + 15}$$

The potential gradient of the wire is given by

$$K = I \times \frac{15}{100} = \frac{2}{R + 15} \times \frac{15}{100}$$

As, the balance point with cell E_2 of emf 75 mV is found at 30 cm from end A

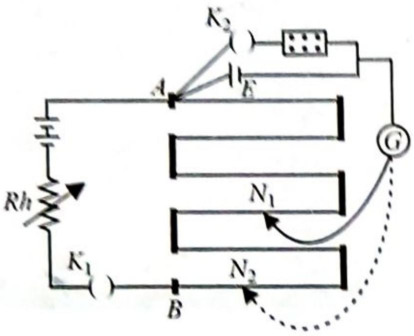
$$\frac{2}{R+15}\times 0.15\times 30 = 75\times 10^{-3}$$

$$\left(\frac{2}{75\times 10^{-3}}\times 0.15\times 30\right)-15 = R$$

$R = 105\ \Omega$

(ii) Potentiometer is preferred over a voltmeter for comparison of emf of cells because at null point, it does not draw any current from the cell and thus there is no potential drop due to the internal resistance of the cell. It measures the p.d. in an open circuit which is equal to the actual emf of the cell.

(iii)



127. (a) Principle of a potentiometer : When a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

Potential gradient : Fall of potential per unit length of the given wire is known as potential gradient.

$$K = \frac{V}{l}$$

where K is potential gradient, V is potential across any portion of length l of the wire.

Let V be the potential difference across certain portion of the wire, whose resistance is R. If I is the current through the wire then $V = IR$

We know that $R = \rho\frac{l}{A}$, where l, A and ρ are length, area of cross-section and resistivity of the material of the wire respectively.

$$\therefore \quad V = I\rho\frac{l}{A}$$

$$\Rightarrow \quad \frac{V}{l} = \frac{I\rho}{A} \Rightarrow K = \frac{I\rho}{A}$$

(b) *Refer to answer 123.*

128. (a) *Refer to answer 118.*

(b) (i) The emf of the cell connected in main circuit may not be more than the emf of the primary cells.

(ii) The positive ends of all cells are not connected to the same end of the wire.

129. (a) *Refer to answer 118.*

(b) The potentiometer wire is made of an alloy, such as constantan or manganin. It is because, an alloy has high resistivity and a low value of temperature coefficient of resistance.

(c) The sensitivity of a potentiometer can be increased by increasing the length of potentiometer wire which is responsible for decreasing the value of potential gradient.

130. (a) *Refer to answer 110.*

(b) *Refer to answer 118.*